

grains and *coups de vent* which would inform the airman of the approach of grave risks should he attempt an ascent until the squall has passed. So far back as 1892 M. Durand-Gréville made the suggestion to meteorologists in a memoir entitled "Les Grains et les Orages," which appeared in the *Annales du Bureau central météorologique de France*. This memoir showed that the isochronic lines marking the commencement of storms corresponded with much longer *isochrones* of squalls. The name *ruban de gain* was attached to a more or less sinuous band extending from near the centre to the circumference of a depression. This band is often 1000-1500 km. (625-940 miles) long, and in its interior the wind is very strong, and often accompanied by precipitation. The advent of the squall is generally marked by a gentle south-west wind veering with startling suddenness and violence to the north-west, masses of cloud come up rapidly from the west, and frequently heavy thunder is heard. All these phenomena occur suddenly and practically simultaneously, so that the passing of the squall is easily and definitely observed.

M. Durand-Gréville's proposal is that from those stations first passed over, telegraphic warnings should be immediately dispatched to centres lying eastwards in the subsequent path of the disturbance. Numerous experiments have demonstrated the feasibility and utility of the scheme. Stations west of Paris have sent messages announcing squalls which have subsequently passed over that city at the predicted time.

On the occasion of the great Aeronautical Congress at Frankfort during 1909, the plan was tried by M. Linke, director of the meteorological station there. Fifty-five observers within a radius of 150 km. were asked to notify the director of any squall which passed over their separate stations, and M. Durand-Gréville states that, "save in one or two cases, all the storms which visited Frankfort during this period were known to M. Linke *more than an hour in advance*."

M. Durand-Gréville points out that the expense to any body which undertook the organisation of the warnings would be almost negligible as compared with the money expended in prizes awarded to aviators, not to mention the much greater cost of machines, &c., and the lamentable sacrifice of human life which might, at least to some extent, be obviated. The ordinary forecasts and warnings issued by the various national meteorological offices are far too general to be of use in this regard, but special services might be instituted, as a trial, by some of the societies especially interested in aeronautical matters.

TEMPERATURE OF THE UPPER AIR.

M. M. RYKACHEF has worked out the results of balloon ascents at Pavlovsk, Kuchino near Moscow, and Nizhni Olchedaief. There were sixty-three flights at Pavlovsk, thirty-two at Kuchino, and twelve at Olchedaief, some of which attained a height of 12 kilometres. With regard to the yearly means, the temperature at Pavlovsk was up to 9 km. lower than at Kuchino, the differences increasing up to 3 to 3.5 km., and then diminishing. At 9 km. they change sign, increasing up to a maximum of about 4° C. between 10.5 and 12 km. The difference of temperature between Pavlovsk and Nizhni Olchedaief is much greater, diminishes up to 10 km., where it changes sign, and attains a maximum of 1° between 11 and 12 km. A marked diminution in the fall of temperature takes place at a lower height in Pavlovsk than in Kuchino, and at Kuchino than at Olchedaief, the heights being 9.5, 9.8, and 10.8 km. respectively. The temperature of the isothermic layers is highest at Pavlovsk and lowest at Kuchino. These variations may be explained by the differences of latitude, Pavlovsk being situated at about 60°, Kuchino 56°, and Nizhni Olchedaief 48°, while Pavlovsk is more exposed to the mild influence of a sea climate than the other two places.

At Nizhni Olchedaief the ascents were too few to deduce any satisfactory conclusions with regard to seasonal variations. At Pavlovsk the temperature at all seasons from the ground up to 8.5 to 9 km. was lower than at Kuchino, except that in winter the temperature up to 500 metres was higher, which result accords with the readings taken on the ground for a series of years. The difference of

temperature in winter, spring, and autumn shows a marked increase at about 2.5 to 3 km., changes sign at 8.5 to 9 km., and rapidly increases to the isothermic layers, where the temperature is lower at Kuchino than at Pavlovsk. In summer the difference decreases continually up to 9.5 km., and then changes sign and increases. The height where the fall in the temperature becomes insignificant is lower in all seasons at Pavlovsk than at Kuchino, except in spring, when it is about 10 km. at both stations.

The temperature of the isothermal region is markedly lower at Kuchino. In the curve of monthly means is seen a retardation of the maximum in the higher layers of air. In the lower atmosphere the maximum occurs in July both at Pavlovsk and Kuchino, but at greater heights it occurs in August, the change taking place at a height of 2.5 km. at Kuchino and at 4.5 km. at Pavlovsk. At 9 km. the maximum returns to July. The minimum exhibits somewhat similar variations. Amplitudes and gradients, mean changes of temperature with elevation in cyclones and anticyclones, &c., are also discussed, with numerous tables and diagrams, in an article published in the *Bulletin of the Imperial Academy of Sciences of St. Petersburg*, No. 7, 1910.

THE INCENSE-ALTAR OF APHRODITE AT PAPHOS.

AN interesting article by Dr. Max Ohnefalsch-Richter appears in *Globus* of November 17 (xcviii., pp. 293-7), in which he brings forward data to prove his earlier supposition that the first site of Paphos was in the neighbourhood of Randi, in Cyprus. Certain inscriptions from this vicinity showed that Aphrodite, "the unconquerable," sender of Spring, was worshipped, and that an ancient incense-altar had existed there. The block containing the most important inscription is held by Prof. Richard Meister, of Leipzig, to belong to an incense-altar, and he adds that the incense-altar of Aphrodite at Paphos (Homer, VIII., 362; Homeric Hymns, IV., 59) was famous from earliest times.

Last August Dr. Ohnefalsch-Richter was able to identify a semi-subterranean side-chamber in the rock connected with this altar, whence had come the inscribed incense-bowls which Prof. Meister has been deciphering. Dr. Zahn's excavations in the chamber have brought to light some half-dozen further inscriptions in the Paphian script, and he has made a number of valuable discoveries on the hill-side below, among them phalli which again played an important part in the Paphian Aphrodite-worship. The cult carried on on the hill consisted in making incense offerings, as described by Homer; in Dr. Zahn's opinion images were not used originally. A clay statue of about life-size was, however, found in the middle of the altar-chamber, the style indicating a date about 600 B.C. The article concludes:—"We must wait to see what Prof. Meister will make of the hundred and more inscriptions discovered. As yet everything supports my surmise that on the hill of the incense-altar at Randi, not only an incense-altar of Aphrodite Paphia stood, but the most famous, the Homeric, incense-altar of Aphrodite of Paphos."

Early in the article the writer refers to ten inscribed stones from Randi "from secret, prohibited excavations," which were fortunately purchased by someone who generously presented them to the Cyprus Museum. This is additional evidence, if such be required, of the urgent necessity for strong measures by the Government for the repression of illicit traffic in objects of archaeological interest in this island and elsewhere. A. C. H.

AIMS OF ASTRONOMY OF PRECISION.¹

THE science of precise physical measurement is one which does not readily appeal to those not immediately concerned, either with the methods or results. An authoritative statement that the sun's distance from the earth is 92,880,000 miles may excite wonder, but scarcely more than will the statement that it is approximately

¹ From the presidential address delivered before the Royal Society of South Africa on April 20, 1910, by S. S. Hough, F.R.S. Published in the *Transactions of the Society*, vol. ii., part i.

93,000,000, except in the minds of those who are in some measure acquainted with the laborious processes by which the two extra figures are derived. In fact, I have not infrequently heard the methods of observation used described by some such epithet as "hair-splitting." For this reason I think I cannot do better to-night than to describe to you, without entering into technical details of the methods employed, some of the aims and objects to which modern astronomy of precision is devoted, and which render essential none but the highest refinements that human ingenuity can devise.

Perhaps the primary reason why astronomy appeals to the popular imagination in a higher degree than other sciences is that astronomy is *par excellence* the science of prediction. True, the days are now past when an astronomer is regarded, except by the most ignorant, as gifted with supernatural powers and capable of predicting events that can have no conceivable relationship with the objects of his researches, or when an unscrupulous astronomer could utilise his powers of prediction for imposing on the world at large in the face of the criticisms of fellow-workers in collateral branches of science. Nevertheless, it is only necessary to point to any of the leading almanacs to establish the undoubted claim of astronomy to a considerable predictive capacity in its own legitimate sphere. These almanacs, prepared in advance, give from day to day the positions of the sun and moon, the phenomena of eclipses, and various other data with an accuracy which can only be called in question by the most refined tests available to astronomers.

How, then, has astronomy acquired this faculty? The answer to this question is—at least primarily—by continuous and patient observation, using always the most refined methods of physical measurement available.

A well-devised scheme of observation is sooner or later bound to lead to the detection of laws governing physical phenomena if such laws exist. Thus it was the planetary observations of Tycho Brahe which led to the detection of the laws of planetary motion associated with the name of Kepler.

Once such laws have been established and the necessary initial data secured, the science of astronomical prediction would for the future devolve on the mathematician rather than the astronomer, were it not for two sources of uncertainty with which the astronomer must continue to concern himself. It is evident, on one hand, that we cannot infuse into our predicted phenomena greater precision than that derived from the initial data, themselves dependent on imperfect observations. However well the laws governing planetary motions may be understood, the predicted position of a planet to-day depends on its observed positions at some earlier epoch or epochs; and the fallibility of the observations made at these earlier epochs will not only pervade all future predictions, but will inevitably increase in amount as the epoch of prediction recedes from the epoch of observation. For this reason, if the standard of accuracy of prediction is merely to be maintained—and the growing requirements of science will scarcely rest contented with this—continuous observation must be maintained and the data on which predictions are based revised from time to time.

I have dealt so far only with the effects of the unavoidable inaccuracies of observations, even when pushed to their utmost refinement, as influencing results of prediction. A second consideration of even greater importance is the validity of the laws associating the predicted with the observed phenomena. I may illustrate my point again by reference to the laws of Kepler. It is now well known that these laws are only rough approximations to the actual truth, and that though they might serve as a useful basis for prediction over a short interval, a few years at most would suffice, by showing a rapidly increasing departure between the observed and predicted positions of the planets, to indicate that these laws require amendment.

That the direction this amendment should take followed so soon on the original discovery of Kepler's laws was due to the genius of Newton, who showed that the theory of universal gravitation propounded by him not only adequately accounted for the laws enunciated by Kepler, and pointed to their imperfections, but served to coordinate as due to a single cause even more recondite phenomena

such as the leading inequalities in the motion of the moon, the precessional motion of the earth, and the phenomena of the tides. This theory further reduced to order those astronomical vagaries the comets, showing that, so long at least as they remained within the precincts of the solar system, their motions were governed by it, while observations of double stars have established beyond question that even remote parts of the universe are still subject to the same laws.

The dynamical laws propounded by Newton, which to-day virtually form the basis of all astronomical prediction, enable us to trace back as well as to trace forward the history of the solar system, and to confront modern observations with historical records. Needless to say, in but rare instances do these records possess the necessary elements of precision to strengthen the existing data required by the astronomer; but there are important exceptions. For instance, a very small uncertainty in the "elements," which in conjunction with Newton's laws govern the motion of the moon, will produce by lapse of time a large change in the comparatively small area of the earth's surface over which a total eclipse of the sun is visible as such. Thus a record that a particular eclipse was seen as total in a given locality becomes an observation of precision, provided only the chronological date at which the eclipse occurred can be traced with sufficient certainty to ensure the identification of the eclipse concerned.

The confrontation of modern with historical observations of such a character has served to establish beyond question the high degree of accuracy with which the laws of Newton represent the motions within the solar system, and their trustworthiness as a basis of prediction for years, perhaps for centuries, to come. It is, however, on various grounds quite certain that these laws in themselves are not absolute, far-reaching though they are, and that they in turn, like those of Kepler, must be superseded by laws still more exact.

Until such laws are discovered there will always remain an element of uncertainty, apart from that due to the initial data affecting all predicted phenomena—an uncertainty which can only be removed when the phenomena cease to be prospective, and when they can be confronted with later as well as with earlier observations.

The fact, however, that the laws of gravitation yield such a close representation of the observed motions within the solar system throughout historic time renders the detection of a departure from these laws a question of extreme delicacy, but none the less essential, if prediction is to be secured for long periods in advance.

I have selected my illustrations largely from the solar system chiefly on the grounds that, thanks to the Newtonian laws, it is here that, in spite of the immense mathematical difficulties which have had to be faced, astronomical prediction has attained its greatest triumphs. I wish now to divert attention to the stars. In so far as these form the fiducial points to which the motions of the planets and other members of the solar system are referred, it is essential that the positions of a limited number, at least, should be determined with the highest possible accuracy. Any uncertainty in their positions will undoubtedly be reflected in the positions of the planets, and will constitute one of those sources of error so liable to increase with time, and render efforts at prediction, if not entirely nugatory, at least partially ineffective.

The universe of so-called "fixed stars" is not invariable in aspect, though its changes, for the most part, are of so minute a character that they can only be surely detected either by the most delicate measurements or by their cumulative effect over long intervals of time. It is chiefly through a study of these changes that our knowledge of the stellar universe has been acquired in the past, and it is largely to similar means that we look for an extension of this knowledge.

Among changes which lend themselves to observation for this purpose we may enumerate:—

(1) Changes of the intensity of the light of the stars. The origin of these changes, except in a few instances, remains obscure. In certain cases, however, notably in the case of variable stars of the Algol type, a satisfactory explanation of the observed phenomena has been found in the motions of a system, governed by laws similar to those

operating in our solar system, of which the visible star forms a constituent member.

(2) Changes of position due to orbital motion in binary or multiple stars. Where both components of a binary star are visible, these changes readily admit of direct measurement. In other cases the existence of a companion is inferred to account for regular periodic changes of position of the visible component, though this companion cannot be seen either on account of intrinsic want of light or on account of its close proximity to the primary, and the consequent incapacity of our telescope to render the two visually distinct.

These changes are of interest as affording evidence of the validity of the Newtonian laws in systems other than the solar system.

The changes to which I have so far referred are changes which affect isolated stars or groups of stars, but which do not occur, at least to a sensible extent, in the generality of stars.

I come now to the changes of position due to the earth's orbital motion which, on the other hand, may be expected to influence all stars in common. Even where, as in the cases I have already spoken of, their influence is obscured by orbital motion within the system, when once this orbital motion has been thoroughly examined, its laws deduced, and due allowance made for it by computation, we might expect to find the effects of the earth's motion still apparent.

The earth in its orbit round the sun approximately describes a circle of 186,000,000 miles in diameter, and its successive positions in space at intervals of six months are separated from one another by this extent. But experience has shown that recurring changes in the relative positions of the stars, as viewed at intervals of six months—that is to say, from two different points of the universe separated by this vast distance—can only be detected in the case of a limited number of stars, and then only by the application of the most delicate methods of measurement specially designed to bring these changes to light.

To the Cape Observatory and its former director, Henderson (1832-4), belongs the credit of first producing trustworthy evidence of the existence of any fixed star, for which these changes could be unmistakably detected, and which, therefore, was not too remote from the solar system to permit of its distance being at least roughly determined in comparison with the diameter of the earth's orbit. Henderson's discovery has since been fully confirmed by later observers, and other stars likely to yield tangible results have now been examined. As illustrative, however, of the evasiveness of the quantities sought, and the excessive labour by which only they can be derived, though the problem of stellar distance has always been in the forefront of astronomical interest, and has attracted the attention of several able observers, the number of stars for which well-determined parallaxes have been published up to the present day does not exceed some 400. This number is quite insignificant in comparison even with the number of stars visible to the naked eye without telescopic aid. Moreover, the stars investigated have been, in general, selected on the grounds of some *a priori* probability of their possessing a measurable parallax, either on account of apparent brightness or on account of their large apparent motion, and for this reason they can scarcely be regarded as typical of the generality of stars.

In order, then, to gauge the depths of the visible universe it would appear imperative that our base-line must in some manner be extended. The distance of 186,000,000 miles through which we are carried in the course of a single half-year by the orbital motion of our planet round the sun is so small in comparison with interstellar distances as to give rise to changes in the apparent relative positions of stars which, except in the most pronounced instances, are so insignificant in amount as to defy detection even by the most refined processes of measurement we possess.

How, then, can such an extension of our base-line be attained? I have already pointed out that the so-called "fixed stars" are not truly "fixed," but that on close observation it is found that each star has an apparent motion either peculiar to itself or shared by other neighbouring stars which, with it, constitute an independent

system. I refer primarily to the visible motion transverse to the line of sight.

If then our sun, as we may reasonably suppose, is itself a member of the stellar universe, it may be anticipated that it too will not be at rest, but will be moving forward in space, and the visible motions will be those due to the combined effects of the motion of the sun and stars.

That the apparent motions of the stars were not entirely fortuitous, but that they could, at least partially, be co-ordinated throughout the sky as the visible manifestations of a single phenomenon, viz. a translatory motion of the sun with its system of planets through interstellar space, was first pointed out by Sir William Herschel, who further indicated that the point of space to which this motion was directed was situated in the constellation "Hercules."

Before proceeding to the further consideration of this solar motion, I wish first to point out to you how its existence at once suggests a means of "extending our base-line" for the purpose of gauging these interstellar depths. I have refrained from any numerical estimates of the amount of this motion, as this involves philosophical questions into which I do not desire to enter to-night; but in order to fix our ideas it is necessary for me to give you some notion, at least, of the order of magnitude. It is now possible to state with some certainty that the speed of the sun's motion relatively to the stars as a whole amounts to about 20 kilometres per second, and that the space traversed in a single day therefore amounts to rather more than 1,000,000 miles, that in a year to about 400,000,000 miles. Thus the stars, as seen on two occasions a year apart, may be considered as viewed from two points in space separated by this length, and it only requires lapse of time in order to increase the length to an almost indefinite extent.

The great scheme for the photographic mapping of the heavens at present being carried out on an extensive scale by means of the cooperative efforts of the leading observatories of the world will shortly furnish a highly accurate delineation of the skies as seen at the commencement of the twentieth century. This alone has called for concentrated effort extending over some twelve years at least, while it would even now scarcely be safe to say that another ten years will see its completion. An immediate repetition is scarcely to be contemplated, though a subsequent repetition at some future epoch, which may be agreed on by astronomers, forms an essential part of the programme as originally introduced.

When this scheme is completed in its entirety very ample data will be available for the discussion of stellar distribution by the methods I have suggested to you.

In the meantime, however, in such tentative attempts as have been made to fathom the secrets of the universe by means of the study of stellar proper motion, it has been necessary to rely on early recorded exact observations. It will be clear from what I have already explained to you that it is the earliest trustworthy records in comparison with the most up-to-date available which will yield the greatest length of base-line, and consequently the most trustworthy results. For this reason the majority of the discussions hitherto attempted have been based on the catalogue of Bradley, dependent on observations made by him at Greenwich between the years 1750-62. This catalogue contains the places of some 3000 stars observed with a precision far surpassing any similar previous observations, and comparing favourably with the best modern catalogues. The stars selected by Bradley are fairly uniformly distributed over the portions of the sky accessible to him, viz. from the North Pole to 30° south of the equator.

Unfortunately no early catalogue of stars of even approximately similar precision exists for the remaining region of the sky between 30° S. dec. and the South Pole, and the absence of exact knowledge of these regions for the earlier epochs has always hampered these discussions.

The discussions I refer to have generally had as their immediate objective:—

(1) The determination of the precessional constant, *i.e.* the annual amount by which the earth's axis of rotation changes its position in space, and

(2) The determination of the speed of the solar motion and the position of the solar apex, *i.e.* the point in the heavens towards which the sun's motion is directed.

The discrepancies in these quantities found by different investigators, either starting with different data or utilising different methods for the combination and discussion of the same material, had long been a puzzle to astronomers. The key to the situation was at length furnished by Prof. Kapteyn, of Groningen, who, in an epoch-making paper read before the British Association in Cape Town, first pointed out that the apparent motions of the stars indicated, not merely the existence of a single solar apex, but that there were two separate regions of the sky towards which a preference was shown by the directions of motion of the Bradley stars.

This was a phenomenon which could not be explained by a simple motion of translation of the sun, as evidently the sun's motion could not be directed to two different points simultaneously, and the only feasible explanation was that the stars consisted of two groups, and that the motion of the sun relatively to one of these groups differed from its motion relatively to the other, or that, though the stars appeared intermingled in space, they possessed an independent relative motion, which might be regarded as located in one group or in the other, but which was shared by all the stars peculiar to the group.

The theory of the existence of two streams or drifts of stars thus put forward by Kapteyn has since received full confirmation by other investigators, notably by Eddington, who based his examination on the early observations of Groombridge, and by Dyson, who limited his discussion to a selected list of stars possessing considerable proper motions.

Recent investigations at the Cape have led us to examine in somewhat more minute detail the proper motions of the Bradley stars, with the result that, though the phenomena first noticed by Kapteyn stand out as the most prominent feature, certain subsidiary features of no less importance have been brought to light.

I have concerned myself hitherto only with the visible motions of the stars transverse to the line of sight, as derived by the older methods of measurement. The introduction of the spectroscope into astronomical research has opened up vast new fields into which, so far as they relate to the chemical and physical constitution of the sun and stars, it is not my purpose to enter to-night. What I wish rather to emphasise is the value of this instrument as a supplement to the older methods in relation to the geometrical astronomy of position.

In accordance with the principle laid down by Doppler, the wave-length of light received from a source which is either receding from or approaching a receiver will appear to be modified by an amount dependent in a known manner on the velocity of approach or recession. If the receiver takes the form of a spectroscope which permits by any means, direct or indirect, of the measurement of the wave-lengths, and the normal wave-lengths of the lines under examination are independently determined by laboratory investigations, the difference between the observed and the normal wave-lengths will thus afford a means of measuring the velocity of approach or recession of the source of light.

Of the precautions necessary to ensure precision it is not my purpose to speak to-night. The large spectroscope of the Cape Observatory, which we owe to the munificence of the late Mr. Frank McClean, was from the outset constructed with due regard to these precautions, so far as they could be foreseen, for the purpose of determining with the greatest accuracy attainable the radial velocities of stars. The instrument has been already successfully used, and its capabilities have been established in an investigation of the aberration constant of light as depending on the apparent variations in the radial velocities of stars resulting from the earth's orbital motion.

From a relatively short series of observations discussed by my colleague Dr. Halm, this constant has been derived with a precision not inferior to that attained by the best series of older observations, and the capabilities of the method are yet far from exhausted.

At the present time the instrument is being devoted to a series of observations of all such stars as are accessible in the southern skies, the spectra of which present sufficiently pronounced features to admit of measurement, primarily with the view of ascertaining what evidence can

be derived from a study of the radial velocities in regard to the systematic structure of the universe.

A year or two must elapse before the present observing programme is completed, but a preliminary discussion of the observations already secured in combination with the published results derived from similar observations in the northern hemisphere has revealed the existence of anomalies similar to those found from the study of the transverse motions— anomalies which can only be reconciled with the two-drift hypothesis put forward by Kapteyn by the further hypothesis that though both drifts pervade the whole sky, they are not similarly distributed throughout it.

At present, through scantiness of material, from a study of the radial velocities we have been able to do little more than discriminate between the two halves of the sky, which contain, respectively, the greatest and the least proportion of second drift stars. It is, however, a fact of some significance that the former corresponds very closely with that hemisphere which contains the Milky Way, suggesting the phenomenon that Kapteyn's second drift might be identified with the galaxy. It was with the view of examining this suggestion in the light of the evidence which could be secured from the transverse motions of the Bradley stars that the discussions I have sketched to you to-night were undertaken by Dr. Halm.

While they have established almost beyond question the rough features of distribution demanded to reconcile the radial-velocity determinations, they further point to an even more detailed correspondence between the distribution of galactic stars and the distribution of stars of the second drift, leaving but little doubt as to the identity of this second drift with the galaxy. It is this second drift which exhibits evidence of structural unity. As regards the Milky Way, the mere appearance on any fine night affords evidence of a similar character, and it is on this account that we have been able to identify the Milky Way with the second drift rather than with the first.

The significance and origin of this structure are as yet obscure, but the more its details are elucidated and the essential features established the nearer are we to an answer to the question, What is the Milky Way?

To revert to my original text, I have endeavoured to point out to you the methods of research by which an answer is sought to this and similar questions, and to explain to you the reasons why the highest precision attainable is a *sine quâ non* in the conduct of such research. Thus it is that the study of the large-scale phenomena of the universe resolves itself frequently into a study of the minute detail of instrumental appliances, on which must be brought to bear all the knowledge that can be derived from other branches of scientific work. The geologist helps us in the selection of stable foundations on which the engineer may erect our large instruments. Chemistry and physics in our photography, our optical and electrical appliances, are of daily application, while one of the most valued accessories in almost all methods of precise measurement is the spider's web we derive from zoology.

Astronomy, in its turn, has done much in the past, and in the future will doubtless do more, to assist the development of collateral sciences. Thus the geologist cannot afford to ignore, even if he does not accept as conclusive, the evidence furnished by astronomy as to the nature of the earth's crust. Exact measurements of space and time as conducted in physical laboratories are for the most part conducted by methods first designed to suit the requirements of astronomical precision, while in the sun and stars chemical phenomena, which may be studied with the aid of the spectroscope, are taking place on a scale far surpassing anything that can be produced in the laboratory.

The value of free intercourse between workers in the various branches of science is certainly indisputable, and I wish to close my address by reference to the opportunities which our society can afford in this respect. Devotees even of applied, and still more of pure, science in a young country are necessarily few in number and scattered. A large proportion of these will in the early stages of their career have been in close association with one or the other great centres of scientific activity of the world, and to such a feeling of scientific isolation almost amounting to

exile, and consequent lack of stimulus, is almost inevitable. Important as are our publications, it is even more through our monthly meetings and the promotion of personal intercourse that the society can help in its primary duty of the advancement of natural knowledge in South Africa.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE discussions at a conference of teachers in rural schools, held in London on December 28, 1910, under the auspices of the National Union of Teachers, showed that teachers are recognising more fully the desirability of making the education in elementary schools in country districts so far as possible of a practical kind, which will train the children for agricultural and other country avocations in later life. A resolution was adopted unanimously urging that, wherever possible, some teaching in handicraft and housecraft should be given to children in rural schools, and that, where necessary and practicable, centres for instruction in these subjects should be formed. It was suggested during the discussion that central school farms might be established, where practical work on the land could be carried on by boys drafted from neighbouring schools. It was recognised, also, that actual work in a garden abounds in opportunities for the best lessons in observation, attention to detail, never putting off until to-morrow what ought to be done to-day, as well as the cultivation of the virtues more commonly associated with the moral instruction lesson. Another resolution, unanimously carried, deplored the continuance of the partial exemption system, and declared that the time has arrived when no child shall be either partially or totally exempt from attendance at school before fourteen years of age. A discussion on continuation schools in rural districts revealed some diversity of opinion, but the meeting eventually decided that, having regard to the impossibility of satisfactorily organising and coordinating continuation work in rural districts, where children are at present allowed to secure partial exemption from school attendance at the early age of eleven or twelve for the purpose of employment, no exemption, either partial or whole-time, from day-school attendance should be granted until the age of fourteen years is attained, all wage-earning child labour out of school hours under the age of fourteen should be forbidden by law, and these conditions having been secured, a system of compulsory attendance at continuation schools or other suitable educational institutions from the age of fourteen to eighteen, accompanied by provisions which should safeguard young people against undue physical or mental overstrain, should be an integral part of a national system of education.

SOCIETIES AND ACADEMIES.

DUBLIN.

Royal Dublin Society, December 20, 1910.—Mr. R. Lloyd Praeger in the chair.—Dr. J. H. Pollok: The vacuum-tube spectra of the vapours of some metals and metallic chlorides (part i.). By the use of a new form of vacuum tube, made entirely of quartz, which the author has recently devised, he can readily obtain photographs of the whole of the vacuum-tube spectra of the vapours of metals and metallic chlorides. In the present paper the author gives a description of the quartz vacuum tube and photographs of the spectra of the vapours of mercury, zinc, cadmium, arsenic, and antimony, together with photographs of the spectra of their chlorides, under varying conditions. The vapours of the metals and their compounds, so far examined, show substantially the same line spectrum in the vacuum tube that they do when metallic electrodes are sparked in air. When a condenser is introduced in the circuit, the metal and its compound show precisely the same change of spectrum, which would seem to indicate that the changes take place in the vibrating atom. If a large amount of vapour of the chloride is present without a condenser, bands are seen in addition to the line spectrum of the metal, and these appear to be due to the particular compound present, and must therefore be connected with the vibrations of the molecule.

—Dr. G. H. Pethybridge: Considerations and experiments on the infection of potato plants with the blight-fungus (*Phytophthora infestans*) by means of mycelium derived direct from the planted tubers. The theory recently advocated by Massee, that the potato crop becomes attacked with the "blight," not by means of the "spores" of *P. infestans*, but by means of the mycelium of this fungus, which, after lying dormant for a long period, passes from the planted tubers into the nearly full-grown stalks, is criticised, and it is pointed out how difficult it is to reconcile this mode of infection with the well-known facts of the disease. It is shown that, owing to the absence of controls, the experimental evidence on which the theory is based is quite worthless. A repetition of the experiments, carried out by the author with the necessary controls, gave results exactly the opposite to those on which the theory is based.—Rev. H. C. Browne: Some suggested improvement in epicyclic variable gears. The improvement applies specially to the modern bicycle, and consists in effecting the complete separation of the epicyclic train from all the moving parts on the middle speed, so that the friction is reduced to the same amount as if the machine were a single-gear machine, i.e. so that there is no movement except that of the ball races at each end of the axle. The high and low speeds are also improved by getting rid of all friction due to over-running pawls or the unnecessary rubbing of parts. The middle speed is produced directly by the engagement of the driving member with the hub, the epicyclic train being completely detached and in no contact with any of the moving parts. The linking up of the gear train with the drive for the high and low speeds is effected in a simple manner by the use of spring trigger pawls. Some care has been given to the construction of the epicyclic train so that it may be a proper mechanical unit in itself instead of being a somewhat loose assemblage of wheels. With this object, the wheels of the train are provided with friction discs reaching to the pitch lines, and the friction between the elements of the train is thereby reduced to rolling friction.

PARIS.

Academy of Sciences, December 27, 1910.—M. Émile Picard in the chair.—A. Gaillot: The analytical theory and tables of motion of Jupiter, by Le Verrier. Additions and rectifications. These tables represent with sufficient exactitude the observations made between 1750 and 1869. From 1870, the comparison of the observed and calculated positions shows increasing discrepancies. The tables for Jupiter have now been recalculated, and the results compared with observations for the period 1750 to 1906-7.—Paul Sabatier: A method for causing two substances to react in the electric arc. The method described by M. Salmon in a recent note (December 5) was anticipated by the author in 1899.—W. Kilian and M. Gignoux: An attempt to coordinate the levels of the pebble beds and terraces of the Bas-Dauphiné.—The perpetual secretary announced the death of Armand Sabatier, correspondent for the section of anatomy and zoology.—J. Guillaume: Observations of the sun made at the Observatory of Lyons during the third quarter of 1910. Observations were possible on sixty-four days during the quarter. Three tables of the results are given, showing number of spots, their distribution in latitude, and the distribution of the faculæ in latitude.—Maurice Servant: The transformations of surfaces applicable to surfaces of the second degree.—T. Lalesco: Left-handed symmetrical nuclei.—G. Kowalewski: The formulæ of Frenet in functional space.—L. Zoretti: The equations of motion of a viscous fluid.—G. de Proszynski: The application of the gyroscope and of compressed air to taking cinematographic views. The gyroscope is driven by compressed air, and is attached to the camera in such a manner as to suppress or deaden small vibrations.—Jean Becquerel: The positive magneto-optic effect presented by the phosphorescence bands of rubies and emeralds, and the relations between emission and absorption in a magnetic field.—J. Thovert: Photometry and the utilisation of coloured sources of light. A description of a new empirical spectrophotometric method.—Daniel Berthelot and Henry Gaudechon: The principal types of photolysis of organic compounds by the ultra-violet rays. The photolysis of