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The Absorption and Effective Range of the β-Rays from Radium E

BY

Miss A. V. Douglas, M.Sc.

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The Absorption and Effective Range of the β-Rays from Radium E

By MISS A. V. DOUGLAS, M.Sc.

Presented by J. A. GRAY, F.R.S.C.

(Read May Meeting, 1922)

Introduction

It was originally supposed that the β-rays emitted from some radioactive source, such as *Ra.E.*, were homogeneous, that is, of a definite velocity. When absorption curves were first taken it was natural to try a law of the exponential type, $I = I_0 e^{-\mu x}$ where I_0 is the initial intensity of the radiation, I the intensity of the rays transmitted through an absorbing plate of thickness x, and μ the coefficient of absorption. The intensity is not directly measurable, but the assumption is made that it is proportional to the ionization which is produced in an electroscope. The experimental procedure is as follows:

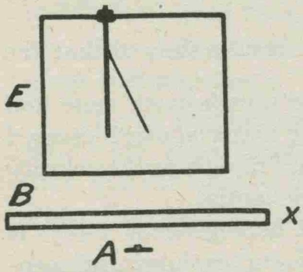

Fig. 1

The active material is placed at A and the ionization is measured by the rate of fall of the gold-leaf in the electroscope E (Fig. 1). The absorbing plate B, of thickness x, is placed in the position as shown, and the ionization as before. The ionization, and hence the intensity, is found to decrease as x is increased. To understand the nature of the absorption it is necessary to determine the relation between I and x.

From the equation given above, it follows that:

$$dI = -\mu I_0 e^{-\mu x} \quad dx = -\mu \, I \, dx$$

$$\text{or } \frac{dI}{I} = -\mu \, dx.$$

Hence for equal increments of thickness dx the ratio $\frac{dI}{I}$ is constant.

A further relation is obtained thus: $\log I + \mu x = \log I_0$. Hence if $\log I$ be plotted against x a straight line curve should result.

Also if I_r, I_s, I_t, etc., represent the relative intensities of rays transmitted through thicknesses x_0, $x_0 + x^1$, $x_0 + 2\,x^1$, etc., then the per cent. transmitted should be constant. That is $\frac{100\ I_s}{I_r}$, $\frac{100\ I_t}{I_s}$, etc., is a series of equal quantities—each equal to $100\ e^{-\mu x'} - d$.

These last two deductions provide very simple tests for exponential absorption, and judging by these, a glance at the absorption curves given in Figs. 4 and 7 and at the percentages shown in Table I makes it evident that the β-rays of *Ra.E.* do not comply with these requirements.

The explanation has been slowly forthcoming. The loss of intensity in passing through matter is brought about in two ways, i.e., (1) By the particles being slowed down or stopped, the energy going probably into ionization and possibly a small part into the production of X-rays.

(2) By the particles being scattered by collision with the atoms of the absorbing material. It is obvious that the scattering loss will be greater the less the velocity of the particles.

In 1900 Becquerel showed photographically by magnetic deflection that the β-rays from radium are not homogeneous. W. Wilson (Proc. R.S., 1909) used this method to isolate an approximately homogeneous beam of β-rays of velocity v, by magnetic deflection in a circle of radius R, under a field of strength H, the velocity being given by the well-known relation $\frac{m\ v}{e} = H.R.$ His results showed that the absorption was not exponential but that the rays became more and more absorbable as the thickness of absorbing material was increased He further showed that the absorption increased rapidly as the velocity diminished and in no case could be called exponential.

One of the best series of experiments on homogeneous β-rays is that of Crowther (Proc. R.S., 1910). One of his curves showing absorption in aluminium is reproduced in Fig. 2, which indicates that for very thin layers there is practically no absorption (similar to the results obtained with α-particles). The increasingly large scattering effect, however, soon alters the slope of the curve and the relative absorption is seen to increase as the thickness of aluminium is increased.

By putting a thin plate of platinum (.001 cm. thick) over the active material and then absorbing in aluminium Crowther found that the curve obtained was very nearly exponential, showing that the character of the rays had been altered by passage through a substance of such high scattering power as platinum.

Later experiments of Wilson and von Baeyer showed definitely that β-rays lose velocity in passing through matter and consequently

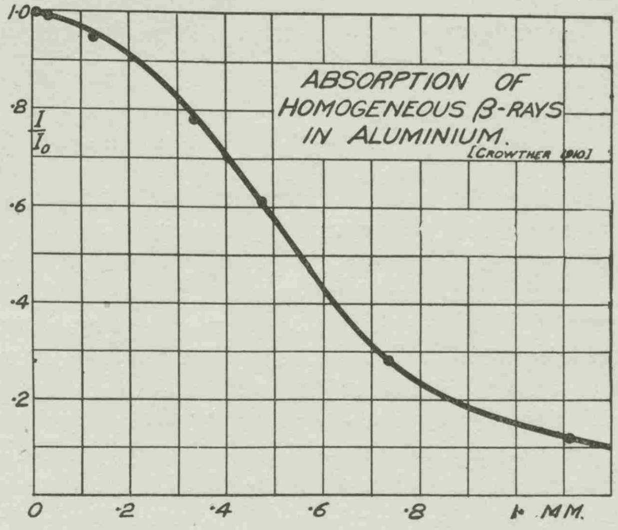

Fig. 2

must have an "effective range," i.e., if there be a given stream of β-rays of any one type there must be some definite thickness of any absorbing material through which the β-rays cannot be detected no matter how great their original intensity.

A very complete description of the experiments referred to above is given in Rutherford's "Radioactive Substances and their Radiations".

It was pointed out by J. A. Gray (Proc. R.S., 1912) that, if β-rays like those from *Ra.E* appear to be exponentially absorbed at first, this can only be an approximation, and a stage must be reached when the absorption increases more and more rapidly until finally the effective range is reached. The values of such terms as $\frac{100\ I_s}{I_r}$, etc. (referred to above), become less and less, the limit being zero when the range is reached. The range can only depend on the fastest β-rays in the original beam, and hence this affords a method of measuring the relative maximum speeds of β-rays from different radioactive substances.

At the suggestion of Dr. Gray, the writer has carried out a series of experiments following the lines indicated above with two main objects:

(1) To determine whether β-rays lose velocity when scattered through large angles.

(2) To determine the ranges of the β-rays in different substances and the relation between range and atomic number.

Part I

When electrons strike a metal anticathode, X-rays are produced. In the same way, when β-rays impinge on matter, a metal plate for example, secondary γ-rays are produced, some of the β-rays are absorbed, some are scattered, and some are transmitted if the plate be not too thick. The question arises as to what relation exists between these various factors. If the γ-rays are due to the scattering of the β-rays then the scattered β-rays should show a loss of energy comparable to the energy of the γ-rays produced. If no such loss is detectable we are justified in assuming that γ-rays are not produced when β-rays are scattered, but when they are stopped by some particular type of collision.

The experimental procedure was as follows: The preparation of *Ra.E* was enclosed in a small lead case (*A*) (see Fig. 3), with one open face and was mounted centrally in front of, but turned away from, the foil face of the electroscope. The latter was a 14 cm. cube. Between it and the active material was placed the absorbing material (*B*), and in front of the active material stood the radiator (*R*). Thus only rays scattered through approximately 160° to 180° could enter the electroscope.

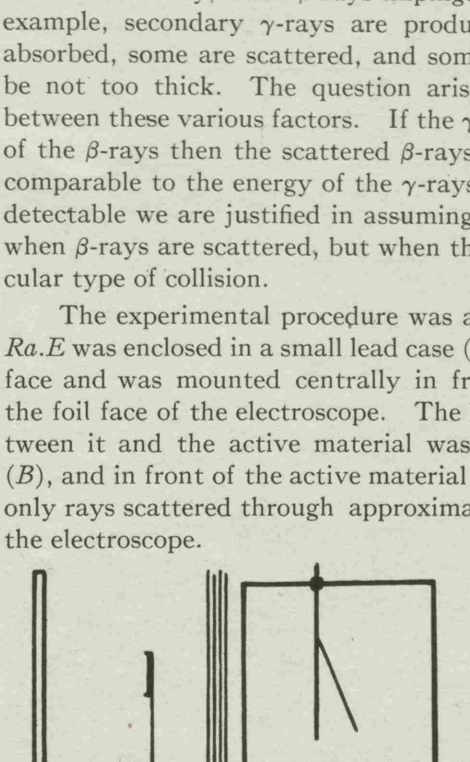

Fig. 3

The intensity of the direct radiation was obtained by replacing the radiator by the active material with its open face towards the electroscope. Corrections had to be made in both cases for γ-rays. This is possible to a high degree of accuracy if the mass-absorption coefficient for γ-rays be known. Those coefficients have been determined for various substances, including carbon and aluminium, by Dr. Gray, who has shown that whereas the mass-absorption coefficient of β-rays in carbon is approximately 16, that of γ-rays in carbon is 0.100. In the case of the scattered radiation a further correction was necessary to eliminate the effect of air-scattering. This presented no greater difficulty than the careful repetition of every reading with the radiator completely removed.

Table I shows the results obtained for (1) Absorption of primary β-rays; (2) absorption of β-rays scattered from a lead radiator, 3 mm. thick; (3) absorption of β-rays scattered from a silver radiator, 0.3 mm. thick. The absorber in each case was paper, each sheet of which weighed 0.00848 gms. per sq. cm.

TABLE I

Absorber		Primary rays		Scattered rays			
				Lead		Silver	
No. of Sheets	Mass gm/cm²	Intensity	$\frac{100\, I_s}{I_r}$ %	Intensity	$\frac{100\, I_s}{I_r}$ %	Intensity	$\frac{100\, I_s}{I_r}$ %
0	0	12000	....	....	....	....	....
6	.0509	4988	....	2000	....	2000	....
11	.0933	2688	54.0	907	45.4	780	39.0
16	.1357	1488	55.3	365	40.3	278	35.6
21	.1781	706	47.5	125.5	34.4	91.5	32.9
26	.2205	311	44.0	39.0	31.1	27.1	29.7
31	.2629	117.92	37.9	10.46	26.8	6.88	25.4
36	.3053	37.22	31.6	2.31	22.1	1.63	23.7
41	.3477	10.22	27.5	0.43	18.7	0.33	20.4
46	.3901	2.52	24.6	0.041	9.5	0.028	8.3
51	.4325	0.50	19.8	....	....	....	....
56	.4749	0.02	4.0	....	....	....	....
61	.5173	0.00	0	....	....	....	....

In Fig. 4 are given the curves corresponding to (1) and (2) above mentioned.

These results point very definitely to the fact that the scattered rays have a range only slightly less than that of the primary rays, because it is certain that practically no primary rays go beyond 57 sheets, while in the case of the secondary rays it is certain that some do pass 49 or 50 sheets. This represents at most only 10 per cent. or 12 per cent. loss of energy as a result of scattering, and for the following reasons it will be shown that this is considered an upper limit, the actual loss being probably very much less, if indeed it exist at all.

(1) It should be noted that only a small proportion of the rays emitted have a very high velocity and it is the effect of this small proportion which has to be accurately measured as the range is approached. From the table it will be seen that at 56 sheets the intensity of the primary rays has been cut down to 1/500,000 of its original value. The difficulty of measurement arising from this reduction comes into play sooner in the case of scattered radiation since the original intensity is much less, and the proportion of high velocity rays is lower since they are less likely to be deflected than the

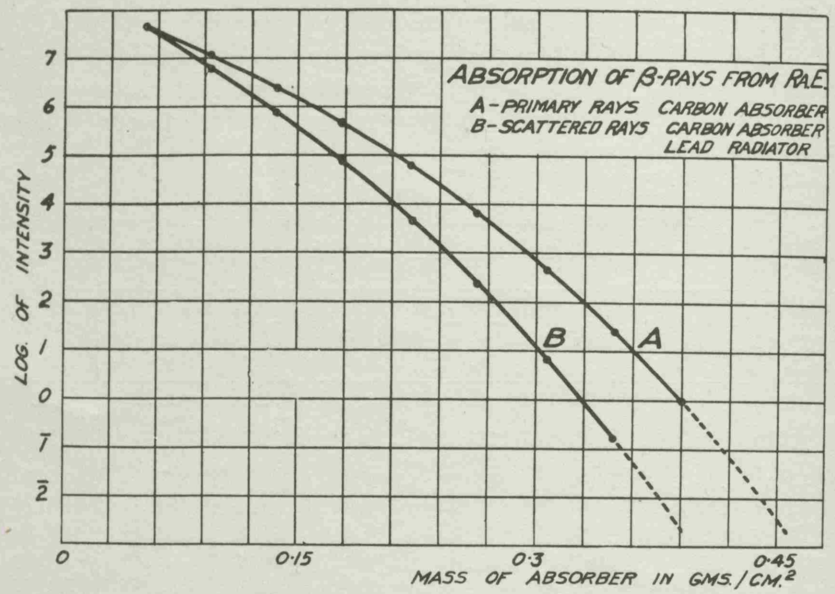

Fig. 4

slower ones. Intensities of this order are much smaller than the natural leak and consequently a slight fluctuation of leak will give a very large error in the apparent intensity.

For these reasons it seems almost certain that with a very intense source of radiation and a more precise method of measurement a measurable quantity of scattered radiation would be detected through a mass of absorber more closely approaching the range of the primary rays.

(2) Scattering is not a surface phenomenon (see Fig. 5). Some of the β-particles will have penetrated a considerable distance into the radiating material before being deflected back, and some will undergo several deflections inside the radiator before emerging backwards. Hence there will be an average distance inside the radiator which the scattered particles traverse, and while doing so they will lose velocity just as has been shown to be the case whenever β-rays pass through matter. It is evident, then, that the real range of the scattered rays is the range actually found plus the equivalent of the average path in the radiator. It is not impossible, though it cannot yet be stated definitely, that this

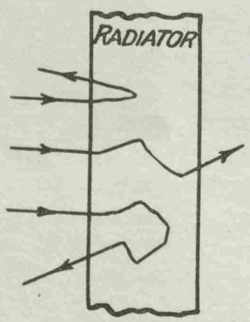

Fig. 5

completely explains the apparent difference in range between the primary and scattered rays, and if so, it may be said that to a first approximation there is no loss of energy due to scattering.

(3) This conclusion is confirmed by the following theoretical considerations:

In the Phil. Mag., Vol. 27, 1914, p. 499, C. G. Darwin gives the calculations regarding the collisions of α-particles with light atoms. In the Phil. Mag., Vol. 21, 1911, p. 684, Sir E. Rutherford states that collisions with light atoms by α and by β-particles obey the same general laws; the main difference being that the probability of a large deflection is much greater in the case of the β-particle due to its mass and its momentum being so much less than the mass and momentum of the α-particle.

It seems reasonable, then, to employ Darwin's method of approach, extending his reasoning to the problem of energy loss.

Consider the deflection of a β-particle of mass M and velocity V due to collision with the nucleus of an atom of mass m at rest. Let ϕ be the deflection of the β-particle and v its resultant velocity; and let the atom be set in motion in a direction θ with a velocity u.

The equations of motion are:

$$MV = Mv\cos\phi + mu\cos\theta$$
$$0 = Mv\sin\phi - mu\sin\theta$$
$$MV^2 = Mv^2 + mu^2$$

and hence $$v = \frac{V}{M+m}\left(M\cos\phi \pm \sqrt{m^2 - M^2\sin^2\phi}\right)$$

The energy of the β-particle before collision was $\frac{1}{2}MV^2$. Its energy after collision is

$$\tfrac{1}{2}Mv^2 = \tfrac{1}{2}M\left(\frac{V}{M+m}\left(M\cos \pm \sqrt{m^2 - M^2\sin^2\phi}\right)\right)^2$$

Hence the loss in energy is given by:

$$\tfrac{1}{2}MV^2\left(1 - \frac{1}{(M+m)^2}\left(M\cos\phi \pm \sqrt{m^2 - M^2\sin^2\phi}\right)^2\right)$$

In the particular case of scattering through an angle of 180°, this loss of energy becomes $\frac{1}{2}MV^2\left(1 - \left(\frac{-M \pm m}{M+m}\right)^2\right)$.

The lower sign gives zero, while the upper sign gives:

$$\tfrac{1}{2}MV^2\left(1 - \left(\frac{m-M}{m+M}\right)^2\right)$$

In the case of β-particles scattered by hydrogen $M = \frac{1}{1800}m =$

1.008, and it is evident that the loss in energy is of a very small order being 1 in 460 or 0.216 per cent. If this theory could be applied to heavy atoms such as lead (207) and silver (108), then the loss in energy is seen to be almost non-existent, actually for lead 0.00105 per cent.

This analysis is based on the assumption that the collision is of the nature of the passage of a comet around a large star, that is to say, considerations of energy-loss due to radiation, and of alteration of mass with velocity are neglected. These points would require special treatment. It is true that, unlike the case of the α-particle, a large deflection of a β-particle may sometimes be the result of many collisions whereby the electron has been buffeted about in an erratic manner for possibly a considerable time before it finally emerged in the direction from which it entered. But on the above theory it would require 10,000 collisions with lead atoms to produce a 10 per cent. loss in energy.

It is, therefore, concluded that the loss in energy is certainly much less than 10 per cent. and is possibly zero.

This is a point of considerable theoretical importance, as it indicates that the phenomenon of the scattering of β-rays does not furnish an explanation of the production or excitation of γ- or X-rays.

Part II

The complex β-rays emitted from a source like *Ra.E* can be represented by a Velocity Distribution Curve of the type of the Maxwellian Probability curves. There will be a minimum velocity v_0 (see Fig. 6) near the origin below which β-rays do not ionize and hence are not detectable as β-rays. The curve will begin at this point, rise to its maximum over $\bar{v}$, where $\bar{v}$ is the most probable velocity, and then fall to a point just short of c where c is the velocity of light. The presence of an absorbing plate in the path of the rays causes a two-fold change: (1) in the shape of the curve, $\bar{v}$ approaching v_0 as the velocity of the transmitted rays is decreased; (2) in the

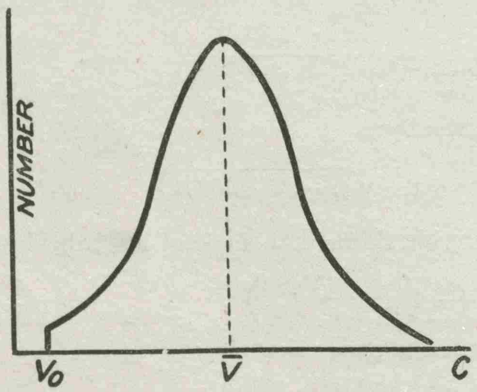

Fig. 6

area under the curve, as some of the rays are stopped or absorbed, and others are scattered through angles greater than 90°.

It is of interest to note that the exponential law of absorption requires that, to a first approximation, the rate of decrease of area under the curve should be constant, due to the combined effects of absorption and scattering through angles greater than 90°, and it may be remarked again that this is proved not to be the case, the area actually decreasing more rapidly as the thickness of absorber is increased.

As the area diminishes and $\bar{v}$ approaches v_0 there will come a time when even the fastest particles have been slowed down so much that they cannot escape complete absorption, hence a range must exist, and that thickness of absorber may be termed the "effective range" which makes the whole curve shrink finally to v_0. The "actual range" which is not directly obtainable experimentally will be referred to later.

The determination of the range in different substances was made by the following method:

A 10 cm. cube electroscope, the base of which consisted of one sheet of aluminium foil (.004615 gms/cm^2) and one sheet of paper (.00848 gms/cm^2), was mounted on the pole pieces of an electromagnet. The active material was placed 6 cm. below the electroscope. The magnetic field was sufficiently strong to deflect between 40 per cent. and 50 per cent. of the primary β-rays unabsorbed, and when their velocity was reduced by about 40 sheets of paper, or its equivalent, complete deflection of the β-rays took place. For small amounts of absorber the intensity with the field off exceeds the intensity with the field on. As the thickness of absorber is increased this excess is diminished until, when the range is reached, the intensities are the same whether the field be off or on.

The difficulties encountered in those experiments, as in all those carried out during the course of the investigation, arose in two ways: (1) The variability of the natural leak and its continued high value and the extreme sensitivity of the electroscope to air currents in spite of the precaution of placing draught-screens around three sides of the apparatus and protecting its base by several layers of absorber; (2) the comparative weakness of the active material which was used for the majority of the experiments, making accurate measurements very difficult when the reduction of intensity was of the order of 1 in 500,000, as has already been explained.

As a result of these, the exact location of the range was not possible to the degree of precision hoped for, but the extreme limits were found by repeated observations and the values shown in Table II as "Average Range" are accurate probably to 0.01 gm. per sq. cm. A correction was necessary due to the permanent base of the electroscope, and the values obtained after this has been made are given under the heading "Corrected Range."

TABLE II

EFFECTIVE RANGE OF β-RAYS FROM RA.E.

Absorbing Material	Atomic number	Average range (gms/cm²)	Corrected range (gms/cm²)
Carbon	6	.462	.474
Aluminium	13	.448	.460
Copper	29	.421	.432
Tin	50	.385	.395
Lead	82	.345	.354
Foil {40 per cent. Sn, 60 per cent. Pb}	(69)	.362	.371

The values here shown can only be considered as the result of preliminary experiments which the writer hopes to continue at some future date.

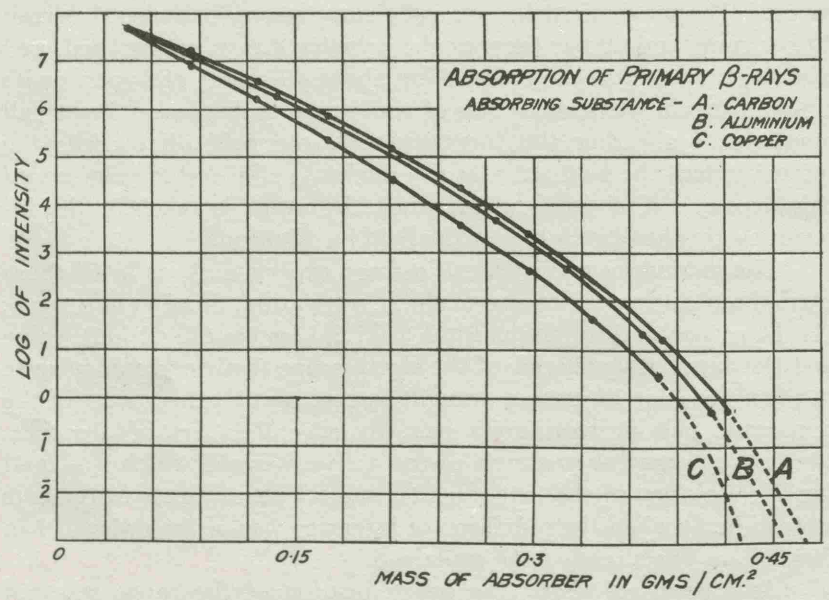

Fig. 7

In Fig. 7 are shown the absorption curves terminating the ranges for carbon, aluminium and copper.

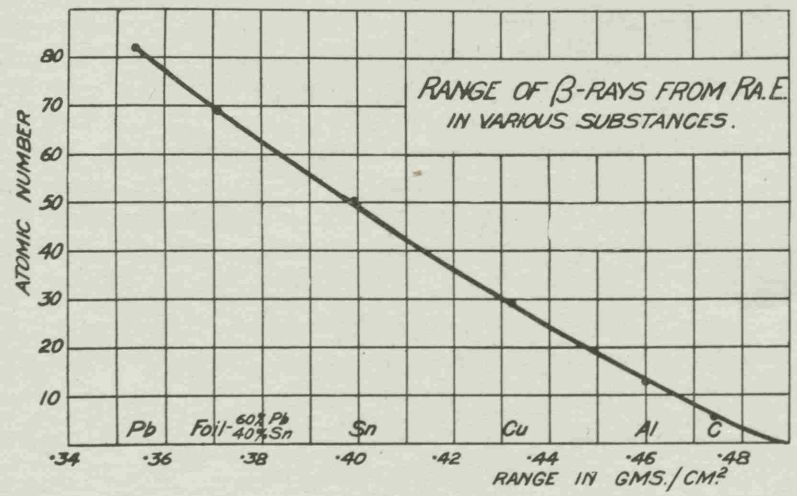

Fig. 8

In Fig. 8 the range has been plotted against the atomic number, and a smooth curve is found to result. It would be necessary, however, to examine the range in many more substances before the relation between effective range and atomic number could be definitely established. By analogy to Crowther's and McClelland's curve of mass-absorption coefficients against atomic number, and Bragg's curve of molecular diameters against atomic number, it seems a plausible forecast that a broken curve of that nature might be found, the breaks occurring at the atomic numbers of the inert gases.

The range of α-particles in different substances has been found by Bragg and Kleeman (Phil. Mag., 1905) to vary very nearly as the square root of the atomic weight. At first sight it appears strange that the range of the β-particle should follow an entirely opposite law and decrease with increase of atomic weight.

This leads to the distinction already referred to between effective and actual range. It will be seen from Table II that the effective range decreases very slightly for large increases in the atomic number of the absorbers. On the other hand, it has been shown by Schmidt and others that the coefficient of scattering increases very rapidly with atomic number. This means that the amount of scattering from plates of equal mass per unit area increases the higher the atomic number of the substance of which the plate is made. The following figures illustrate the increase: Aluminium, 9.7; copper, 70; tin, 100; lead, 266. A high coefficient of scattering means that the β-particle is subjected to many more collisions and consequently its path inside the absorber is composed of many short zigzag paths. The total path or sum of all these separate short paths within the absorber is what is meant by the actual range, where as the effective range is the perpendicular distance from one face to the other. If the actual range could be accurately estimated on the basis of the coefficient of scattering, it seems certain that it would be found to increase as the atomic number increases. Indeed, by means of a special experiment W. H. Bragg, (Phil. Mag. 1910) has shown that this is the case.

The writer desires to express her thanks to Dr. J. A. Gray for his continuous help and valuable suggestions.

Summary

1. Experimental evidence is given to prove that when β-rays are scattered through large angles the loss of energy observed is not more than about 10 per cent.

2. Reasons are given for believing that the actual loss of energy is so much less than 10 per cent. that to a first approximation it may be said that there is no loss of energy due to scattering.

3. The effective ranges of β-rays in carbon, aluminium, copper tin, lead and mixed foil are given.

4. The distinction is drawn between "effective" and "actual" range and evidence is given to support the statement that whereas the effective range decreases with increase of atomic number, the actual range increases with increase of atomic number.

The Academic Atmosphere in Africa

by

A. Vibert Douglas

An emeritus professor of astronomy reports on a visit to some African universities.

IN the spring and early summer of 1964 I visited eleven countries of Africa. In nine of these my main objective, with the blessing of the Canadian Universities Foundation, was to visit the universities and learn something of the educational needs and problems of these countries at all levels. The blessing of the C.U.F. was a large contribution towards the cost of such an extended journey; but it did not include any introductions. Thus, every day was an adventure and at each university I made my contacts as chance dictated. To say that the dice seemed loaded in my favour would be an understatement.

In Egypt and South Africa I made almost no university contacts. My reasons for visiting these countries are readily imaginable. But in Sudan, I first encountered the educational conditions that are fairly typical throughout the newly self-governing countries. The Vice-Chancellor of the University in Khartoum is a Sudanese scholar. His faculty is predominantly expatriot, i.e. non-African. The doors would close tomorrow were the expatriot professors to leave their posts. In the Department of Geography I met Professor John Randell. He and his wife, who teaches in a secondary school, are both U.B.C. graduates. The number of graduates in these African countries is small and the young scholars who win their degrees each year are, with few exceptions, not coming back into academic work—government appointments and the professions, law, medicine and engineering, offer greater remuneration and rapid advancement. Ignorance on my part left me totally unprepared for the surprise of finding Canadian professors in nine of the ten universities which I visited in central, east and west Africa. Most of their colleagues are from the British Isles, the U.S.A., Australia, New Zealand, and a few are Asians, most of them born in Africa.

English is the language of higher education in all those countries formerly under British rule. Many of these universities, now no longer University Colleges of London, retain the practice of bringing in external examiners at the close of the academic session. These contacts help them to obtain replacements for their foreign staff and research fellowships for their most promising graduates. I met several of these examiners from British universities, in both Khartoum and Nairobi, enthusiastic about the high quality of the best students, equal to any anywhere in their opinion.

A recurring complaint was the poor teaching in primary and in most secondary schools leading to inadequate preparation for university work. In the Sudan the spirit of nationalism had led the government to decree that Arabic, not English, should be the language of instruction in secondary schools. English has become simply one language course and students are now entering the university unable to speak and read it fluently. Furthermore the Muslim education leans heavily on memorization of the Koran, a drill which does not develop the ability to reason. The heavy failure record in the first year is causing grave concern in the university.

The need for overseas teachers is a serious problem in all these countries striving towards the goal of education for all children. Unesco is doing valuable work in organizing and underwriting courses for untrained African primary and secondary teachers, working with the education departments of the universities wherever possible. To help meet the desperate teacher shortage as well as the needs in public health, welfare, agriculture, etc., the Canadian University Service Overseas is performing a task which deserves the support of citizens both within and without our universities. In Ghana I was able to see some of these C.U.S.O. teachers and note their enthusiasm as well as their realization of the enrichment of their own lives which this two year sojourn in Africa was giving them.

In Addis Ababa at Haile Selassie I University, English is also the language of instruction. Some 1500 students are registered, about 500 fewer than in Khartoum. Here, too, the staff is an international one. The director of the active Institute for Ethiopian Studies is an Englishman; of the Department of Drama, Music and Art, an American; of Physics and Geophysics, respectively, French Canadians, Rev. M. Gouin and Dr. Emile Cambron; of Education, an Ethiopian. The Department of Agriculture is sponsored and staffed by Oklahoma State University, one of whose professors is doing research on utilization of solar energy, another on the conversion into cattle and chicken feeds of "waste" products (black strap molasses used to be poured onto the roads). In the Department of Religion, Coptic scholars are endeavouring to formulate a modern restatement of their ancient faith. Archaeology is flourishing, largely under French guidance, 4th century stone inscriptions being a special challenge. One of the oldest pictorial records of the Queen of Sheba and her journey to and from the court of King Solomon covers a large wall in the University Museum. In one section their twin sons are depicted playing a game reminiscent of field hockey. One of the boys died young, the other became Menelik I, progenitor of the line of Emperors of Ethiopia — the Lions of Judah, Elect of God — of whom Emperor Haile Selassie I is the present representative. He is the Chancellor of the university which bears his name.

The newly formed University of East Africa brings together three existing institutions: (1) Makerere University College of Uganda in Kampala with Arts and Science and a large Medical School; (2) The University College of Kenya in Nairobi with Arts and Science and a School of Engineering; (3) the University College of Tanzania in Dar es Salaam with Arts and Science and a Faculty of Law. These three colleges have some 1500 students between them, and until the numbers are very greatly increased it is not intended that duplication or triplication of the three professional faculties should be attempted. Makerere College is the oldest. Much active research is in progress in medicine and public health; a Netherlands scholar directs Mathematics; a Canadian historian heads his department, Professor R. W. Beachey (Queen's University); a Polish archaeologist is active in his field and an Institute of African Studies attracts graduate fellows from many lands. In Nairobi the head of Zoology is a Canadian, Dr. Bristol Foster (U.B.C.), and a lecturer in Mechanical Engineering is a Kenyan born Indian who had held a Commonwealth Fellowship at McGill, Mr. R. P. Patel. I talked also with members of the Physics Department about their research in geomagnetism of the younger volcanic rocks, with a botanist just returned from a field trip to the high, lonely regions of north west Kenya, and with three members of the Department of Art and Commercial Art, the senior of whom contrasted the rich native art of the west coast with the absence of any indigenous art in East Africa. Here, too, I met Dr. D. Harmsen (Groningen and Queen's) engaged in sleeping sickness research, and his wife (a Queen's graduate), who taught in the Department of Zoology.

In Dar es Salaam the College has made great strides under its far-seeing Canadian Vice-Chancellor, Principal R. Cranford Pratt, who was about to hand over his office to a native Tanganyikan scholar. From the inadequate quarters in the city, the College has moved inland to a splendid new campus spanning three hills with a panoramic view over city and harbour. This will be a spacious and attractive "University City" when all its buildings and residences for staff and students are completed.

My next port of call was Salisbury. Here in Rhodesia the university is still a University College of London and hence completely free from the racial prejudices so tragically growing in momentum in the country as a whole. It moved a few years ago to an extensive campus in a suburb. Here, about 560 students were enrolled of whom only some 150 were Africans even though the College served Zambia and Malawi and attracts students from yet other countries. I met the able and courageous Vice-Chancellor, Dr. Walter Adams (from Great Britain), the energetic New Zealander who holds the chair of Education, and two Cambridge physicists to whom I became almost a specimen out of Noah's Ark when I began reminiscing about Lord Rutherford! Most of the faculty had just left on vacation. I learned of the deplorable lack of educational facilities for the African children — only two government secondary schools for them, and to only one of these are African girls admitted. From these and from the primary

schools the Government of Rhodesia reserves the right to expel any child charged with "insubordination" with no hope of readmission — an iniquitous policy which is bitterly antagonizing the youth of the country. When I asked whether a mission school would not take in these rejected children, I was told that government inspectors would make sure that this did not happen. But within the university a healthy free academic atmosphere was evident. Special classes had been organized to salvage a good proportion of the African students who had failed the entrance examinations due to the poor instruction in the schools. Graduate research was encouraged, but of this I only saw what is going on in upper atmosphere physics and in the geomagnetism of ancient rocks.

In Yaoundé, the capital of the Republic of Cameroun, a vigorous young university is being built with substantial help from the French government. The Vice-Chancellor is from the University of Toulouse. Several French Canadians are on his staff and at least one Englishman whose role is to teach English to the French-speaking majority of students. Here a great experiment in bilingualism is beginning. The situation in the Republic parallels in reverse the situation in Canada. There the minority (from the western province, formerly that section of British Cameroon which refused to join Nigeria) have acquired English as their language of higher education, government and commerce. For the majority, French plays this role. The policy of the university is therefore to make all their students, some 300 a year ago, truly bilingual and able to attend lectures in either tongue. In the Faculty of Law not only will French law be studied but a McGill-trained bilingual professor was this year to begin instruction in English law under which West Cameroun operates.

Unesco is supporting two important projects in Cameroun. One is the Agricultural Research Institute affiliated with the university. The other is the bi-cultural literary magazine, *Abbia*, a scholarly monthly unique on the African continent.

Arriving at Lagos on the third day of a nation-wide general strike, I found telephone, telegraph and railway services at a standstill, most shops, banks and the larger hotels closed, and internal air lines completely disrupted. Although maintenance staff had walked out of the university, the doctors and nurses were shouldering the extra load and carrying on their work at the University of Lagos Medical Teaching Hospital. Three at least of this devoted group of doctors were Canadians, two of whom, Dr. Shirley Fleming of Toronto and Dr. Earl Russell of Kingston, and an Indian doctor had just published results of research on the clinical use of a new anaesthetic. The younger Arts, Law and Science Faculties were looking forward to a new campus near the sea at some distance across the city from the Medical School. They had a registration of over 400 students.

Due to the strike the only inland university which I could reach was at Ibadan, the largest native city of Middle Africa. Residences on its beautiful rolling, well wooded campus can accommodate over 2000 students in Faculties of Arts, Science, Law, Agriculture, Veterinary Science and Forestry. A large hospital and medical school are on another fringe of the vast crowded city. The Principal and Vice-Chancellor, Dr. K. O. Dike, is an internationally known authority on African history. One of his graduate students, a Canadian, Dr. J. B. Webster (U.B.C.), holds the chair of History previously occupied by the Principal. Eighteen graduate students are now at work on African history, and over 40 are registered for higher degrees in other departments. It is interesting to know that Dr. Dike studied with Professor Gerald Graham at King's College, London.

My journeyings in Africa ended on the coast of Ghana where the University at Legon on the outskirts of Accra greatly impressed me. Attractive buildings are widely spaced over a large campus. About 1500 students are now in attendance. Less than 10% are women which is typical of the universities visited, with the exception of Makerere University College with 20% women though it should be added that only a minority of these were African. But typical, too, is the growing realization that a country needs educated women as well as men. An Ethiopian lecturer had stressed one aspect of this when he said that the pressure for education of girls and women in this country was coming from the educated young men. The relatively few highly educated women in these countries of middle Africa have advanced rapidly to positions of responsibility in government, education, medicine and law.

The faculty at Accra included several Canadians who have made notable contributions; one, Mr. David H. Jones (Dominion Bureau of Statistics), by establishing the Institute of Statistics; another, Mr. J. D. Marr (formerly of Chalk River) as technical adviser to the Radio-isotope unit; another, Mr. G. Dargie (U.B.C.), in the Faculty of Agriculture and yet another, Rev. Dr. J. R. Koster, in charge of upper atmosphere physics. On view in the fine university library was a display centring on the Volta dam project, the result of researches by geographers, geologists, botanists, icthyologists, archaeologists, ethnographers and engineers.

From Canada's representatives in the Embassies and High Commissioner's Offices in five African countries I received great kindness and thoughtful assistance. Any itinerant professor expects to find a congenial and familiar atmosphere within a university anywhere, whether it be in Montevideo or Mexico, in Oslo or Warsaw. With this expectation I approached these African institutions of learning and very quickly felt at home in their academic atmosphere. The winds of progress are blowing vigorously. One is not unaware of contrary winds stirred up from without through misunderstanding and ignorance; but this is not a problem found only in Africa. There, as here and wherever academic freedom is at stake, the only answer is a strong resolute counterblast from within. That spirit is not wanting in Middle Africa.

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R.A.S.C. PAPERS

AL-BIRUNI, PERSIAN SCHOLAR, 973–1048*

By A. Vibert Douglas

Kingston Centre, R.A.S.C.

Abu Raihan Muhammad bin Ahmad al-Biruni was born on September 4, one thousand years ago.

One of his scientific books written between 1018 and 1025 begins thus:

> In the name of God, most gracious, most merciful. Minds have a pressing need for expanding their domains of activities, and souls cannot be satisfied without spiritual contemplation. Hence it is my ambition to present what passes through my mind concerning the creation of an art, or the perfection of the projected shadow of knowledge; so that on beholding it, the mind shall see the shadow most beautifully clothed and shall find in it the satisfaction which is inspired by its virtues of excellence and permanence for all time.

His attitude to scholarly investigation is stated thus:

> ... an observer should keep alert, constantly scrutinizing his work, promoting his self-criticism, moderating his self-admiration, and pursuing his researches without impatience or boredom.

Al-Biruni, perhaps the greatest scientist of his day and a productive scholar in many other fields, was born of Persian parents in 973, in the territory of Khwarizm (now called Khiva), a region lying south of the Aral Sea, struggling to keep a measure of independence from the rulers of Central Asia. He early became a counsellor at the court of the princes of the House of Ma'mun, but civil war compelled him to seek safety in 999 in Gurgan with the ruling prince al-Ma'ali to whom he dedicated in the year 1000 his major work on the *Chronology of Ancient Nations*.

From 1010 to 1017, he lived again in Khwarizm, but internal strife once more broke out and al-Ma'mun was murdered. Sultan Mahmud of Ghazna conquered the land, thus extending his empire north-westward. His court was a centre for poets and scholars. To join this learned group, al-Biruni was brought to Ghazna as a hostage in 1018, and here in Afghanistan, he died in 1048, the generally accepted date, or 1050, according to Professor Jamil Ali of Lebanon.

*Presented at the 1973 General Assembly, in Ottawa, May 26.

1973

Between 1018 and 1025, al-Biruni worked on his *Determination of the Co-ordinates of Cities*, in which he explained the methods for finding latitudes and longitudes, the Qibla, and the inclination of the ecliptic, with the plane and spherical geometry involved. The Qibla was important to every Muslim, being the azimuth of Mecca towards which a devout follower of the Koran bowed in prayer daily. Longitudes are given relative to the meridian of Baghdad and the positions of a dozen cities east and west of Ghazna were determined and their distances cross-checked. Eratosthenes, Hipparchus, Ptolemy, and other Greek sources as well as Arab astronomers, are quoted, and his own determinations for inclination of the ecliptic defined as half the arc between the two solstices. The final value at Ghazna is given as $23° 35'$, but his earlier solstice observations at Khwarizm had given $23° 35' 50''$. Observations of lunar eclipses and one partial solar eclipse are recorded.

Accompanying Sultan Mahmud on many expeditions into India as his counsellor and court astrologer, gave al-Biruni opportunity to observe the customs of the Hindus and to study their astronomy, astrology, language, philosophy, religion, and literature, as well as the history and geography of the country. In 1030, he began his great treatise on astronomy. the *Mas'udi Canon*, dedicated to Sultan Mas'ud of Ghazna, son of and successor to Mahmud. This was an encyclopedia of astronomical sciences. In it he wrote, "I do not scorn to accept truth from whatever source I can find it." The Ministry of Education, Government of India, had this great compendium translated and published in 1954 with the comment, "No other scholar before or after him has combined the study of all that was available in his times from Indian, Greek, and Muslim sources, and at the same time, left behind him so many original contributions on numerous spheres of learning." Al-Biruni was familiar with Persian, Sanskrit, Turkish, Hebrew, and Syriac, and wrote all his treatises in Arabic. He could not read Greek or Latin, but devoured the Arabic translations of their scientific and philosophical works. Among Muslim writings, he found speculations about the motion of the earth relative to the sun, admitting his inability to prove or disprove this, but he discussed with approval the diurnal rotation of the earth which made possible determinations of longitude from records of time of solstices as reported by astronomers from Alexandria to Ghazna. He believed the universe could not be eternal, giving as evidence the terrestrial changes in rock and land surface due to natural forces like wind, water and fire.

His massive book on India, written about 1032, has placed him among the greatest Indologists. It ranges over geography, climate, customs, laws, religion, literature, and philosophy. He believed geography was an essential background for an historian. He propounded the daring theory that the valley of the Indus was once a sea bottom. He was a Muslim of the most liberal and tolerant kind, far removed from the bloodthirsty sects of Islam. His deep appreciation of Hindu philosophy, when stripped of vulgar imagery, led to a critical but sympathetic appraisal of its similarities and contrasts with the Koran and with the noblest Greek philosophy.

But al-Biruni's genius lay most creatively in mathematics and astronomy. Among his writings are Indian arithmetic and the books, *Mathematics, Trigonometry Applied in Astronomy*, *On Transits*. He invented a new type of astrolabe. He discussed ratio and proportion, extraction of cube roots, chords and tangents, heights and distances, time, days and nights, the phases of the moon, twilight, eclipses, comets, meteorites, measurement of the radius of the earth by dip of the horizon, the equator, projective geometry of spheres on planes, spherical astronomy used for ascensions of signs of the ecliptic and in great detail, astrology as practised in Persia, in Greece and in India. He did not believe in alchemy, condemning it vigorously as intentional deceit in contrast to chemistry and mineralogy.

When staying at Nandana in India, he calculated the height of a nearby mountain, and from its summit, observed the dip of the horizon as 34′ of arc. From these figures, he deduced the radius of the earth as 12,803,337 cubits! A cubit is variously given as 18 inches to 22 inches. The former gives the earth's radius as 3,600 miles, the latter as 4,400 miles, neatly spanning the true value.

Al-Biruni's interest extended also to medicine and brought him into correspondence with another somewhat older Islamic scholar, Avicenna. He compiled a *Materia Medica* from Islamic and Indian sources and practice. He is credited with the earliest known diagram illustrating Caesarian section.

In the *al-Biruni Commemorative Volume*, produced by the Iran Society in Calcutta in 1951, the Iranian ambassador to India, M. Noury Espandiary, wrote, "The Shiekh's disinterested pursuit of truth, his relentlessness as a perturbed spirit, his breadth of mind, his versatility of genius, his vision, his unbounded love for human culture, are and will remain forever as beacon lights for the caravan of misguided humanity. ... We must shed off narrow-mindedness and all the fissiparous tendencies against which the great master waged a relentless war all through his life."

Al-Biruni deserves to be remembered and honoured by all who cherish the scholarly pursuit of knowledge.

REVIEW OF PUBLICATIONS

Boundaries of the Universe by John S. Glasby. Pages 296; 5½ × 8½ in. Harvard University Press, Cambridge, Massachusetts, 1971. Price $11.00.

This work is an attempt to cover several rapidly expanding areas of astronomical research. Unfortunately, Glasby occasionally lapses into a textbook format, so that the reader can at times find the book frustrating to read. He examines a wide variety of topics including planetary exploration, quasars, pulsars, cosmology, and extraterrestrial life – topics which often receive short shrift in general works. A separate chapter on Seyfert galaxies is even included. Glasby particularly exploits his own expertise in variable stars and spectroscopy (being an expert in the former by avocation, in the latter by vocation); his chapters on variables and novae are among the clearest and most detailed of any book at this level.

However, his coverage is sometimes uneven: he introduces scientific principles on an elementary level and then plunges into detailed accounts of theories and observations which assume a higher level of knowledge. For example, his first chapter (on astronomical instruments) and sixth chapter (on distance in astronomy) are too elementary for the reader who can easily comprehend the astrophysical discussions that follow. He could either have left the chapters out entirely or written them on a more technical plane. Chapter sixteen, on relativity (which *follows* the discussion of cosmology), is gratuitous. He offers only a pedestrian account of Einstein's theory and ignores the rapidly progressing field of relativistic astrophysics. The book is also marred by typographical errors, mis-labelled diagrams, and the same, tired photographs from the Hale Observatories.

This genre of book becomes rapidly dated, but some of Glasby's discussions (such as that on stellar evolution) should endure for several years. His book can be recommended to the advanced amateur or keen undergraduate who (if he has patience) can glean a considerable amount of interesting fact and theory from it. Certainly, anyone wishing an up-to-date survey of variable stars should consult this work.

RICHARD A. JARRELL

ARTHUR STANLEY EDDINGTON

By A. Vibert Douglas

President of the Royal Astronomical Society of Canada

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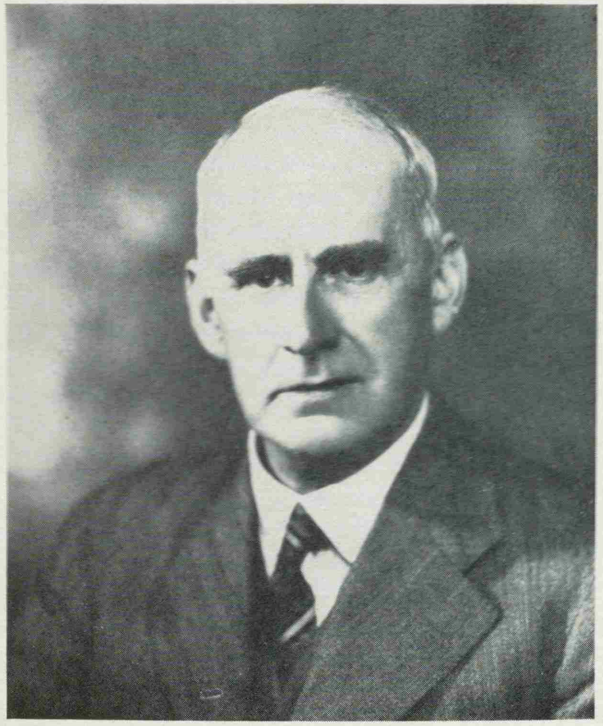
Plate I



Sir Arthur Stanley Eddington
(1882-1944)

(Photograph by Lafayette, Ltd., supplied by courtesy of Harvard Observatory.)

ARTHUR STANLEY EDDINGTON

By A. Vibert Douglas

President of the Royal Astronomical Society of Canada

(With Plate I)

TO the memory of a great and good man, Sir Arthur Stanley Eddington, O.M., F.R.S., and in recognition of his contributions to physical science and to philosophy, the Royal Astronomical Society of Canada pays its tribute.

Had Sir Arthur lived until the Annual Meeting of this society in January 1945, he would have been one of the first two Honorary Members of the R.A.S.C. to be elected under its new Constitution. The committee charged with the selection of Honorary Members placed his name before General Council in the following terms:

We nominate for honorary membership—

Sir Arthur Stanley Eddington, O.M., M.A., D.Sc., LL.D., F.R.S.
Plumian Professor of Astronomy in the University of Cambridge.

Sir Arthur Eddington has been contributing to the progress of astronomy and cosmology for about forty years in fields as diverse as stellar movements, internal constitution of the stars, (radiation pressure, pulsating stars, stellar diameters and densities, white dwarfs, central temperatures), mathematical theory of relativity, cosmological and physical constants, combination of relativity and quantum theories. His papers before the Royal Society, The Royal Astronomical Society and other national and international scientific bodies have placed him in the very forefront of the world's scientists. His expositions in *The Nature of the Physical World, New Pathways of Science, The Philosophy of Physical Science*, have been stimulating to scientists, philosophers, metaphysicians and thinking laymen in many countries. His insight and powerful thinking have placed his work at the foundations and within the superstructures of many investigations still in progress. We are proposing an honour to our R.A.S.C. in suggesting that Sir Arthur Eddington be asked to accept honorary membership.

In 1882 Eddington was born in Kendal, Westmorland. From Owens College, Manchester, he went to Cambridge where he became Senior Wrangler and Smith's Prizeman, Fellow of Trinity, F.R.S., Plumian Professor and Director of Cambridge Observatory, before he was thirty-two. During seven of these years he was Chief Assistant at Greenwich and concentrated on investigation of stellar movements, star streaming, and the structure of the galaxy, devising an effective way of projecting proper motions in different regions of the celestial sphere so that general trends would emerge.

From 1913 until his death on November 21, 1944, he resided in Cambridge, though meetings of the International Astronomical Union and the British Association, or special lectures and visits took him across three continents.

Eddington has been the prime interpreter of relativity theory in the English language. His powerful mathematical ability and insight made it possible for him to grasp the significance of Einstein's work against the background of Minkowski and the pioneers. DeSitter, Weyl, Eddington and later Lemaître, provided the early criticisms and developments of the theory. Eddington published a *Report on the Relativity Theory of Gravitation* and *Space Time and Gravitation* in 1920, followed soon after by *The Mathematical Theory of Relativity*, and in 1938 *Relativity Theory of Protons and Electrons*. He has consistently upheld the theory of an expanding universe since 1930 and from this cosmological basis combined with quantum theory he has developed his most daring work—the synthesis of a world structure relating all the fundamental physical constants. From three measured constants—the velocity of light and the Rydberg and Faraday constants for hydrogen—his theory enables him to calculate with no further dependence upon observation thirteen constants including the charge on an electron and its mass, the mass of a proton and a hydrogen atom; Planck's constant, gravitation constant; mass of the universe, number of particles in the universe and speed of recession of the spirals. The agreement of ten of these quantities with the values determined in laboratory or observatory is so remarkable that his theory deserves the closest scrutiny by those with the mathematical ability to do so critically. Max Born, like Herbert Dingle, dislikes the Aristotelianism of this work, and attributes its success to

Eddington's "personal genius and insight." These and other qualities enabled him to "spin the gossamers as well as forge the anchors of the mind" and who shall say what of his work future assessors will regard as his profoundest contributions?

The name of Eddington will always be associated in the minds of astronomers with some of the great peaks in the advance of this science in the last three decades: the first verification of the Einstein deflection of light from Eddington's eclipse photographs at Principe Island and Crommelin's at Sobral in May 1919; his recognition of the importance of radiation pressure as a prime factor in stellar stability; the theoretical calculation of stellar diameters and of the density of Sirius B; the Mass-Luminosity law; the central temperatures of stars; interstellar gases; the age of the universe. His books in these fields are *The Internal Constitution of the Stars* and the non-mathematical smaller books *Stars and Atoms* and *The Expanding Universe* and his Bakerian and Halley lectures.

Eddington's three books dealing with philosophy and physical science are already mentioned. Add to them his Swarthmore lecture *Science and the Unseen World*, and we have a body of literature, rightly so called, for it has great literary merit as well as being a source of penetrating honest thought and brilliant exposition. With rich metaphor and striking analogy, sometimes with subtle humour and sparkling wit, the symbolism of mathematics is translated into words as he unfolds the significance of relativity and quantum theories, wave mechanics, indeterminacy, theory of groups, probability, and speculations in cosmology.

In compiling his philosophy, Eddington recognizes that the problem of experience has dual aspects—experience resulting in sense data in the realm of physical science which embraces all that is measurable, and a different but complementary kind of experience which is an awareness of values and of the significance of things immeasurable and unseen save by the eye of the soul. No philosophy is complete which does not include both types of experience. His philosophy of science dealing with the symbolic world of physics is best described as Selective subjectivism and Structuralism, to use his own terms. But the same urge from within man's spirit which drives him to seek truth and evaluate experience in the physical world, drives him with equally logical reasonableness to seek truth through spiritual apprehension, and to evaluate experience of beauty in nature, in art, in human personality, and in "the sense of a divine presence irradiating the soul." Faith, he insists, is fundamental to both approaches to the problem of experience. "In an age of reason, faith yet remains supreme, for reason is an article of faith."

The modern world owes much to the Society of Friends which has produced many men of great and good influence. This debt is immeasurably increased when we remember that Sir Arthur Eddington was of that company of devout seekers after truth. *Cum illo sint animae nostrae.*

Queen's University,
Kingston, Ontario,
1944, December 5.

ASTRONOMERS VISIT FOUR U.S.S.R. OBSERVATORIES

By A. Vibert Douglas
Queen's University, Kingston, Ontario

After the final meeting of the General Assembly of the International Astronomical Union in Moscow on August 20, 1958, various members, who did not have to leave the U.S.S.R. immediately, availed themselves of the opportunity to see something of the south central or of the south western regions of the Soviet Union. I selected the tour which kept me longest inside the country, the 9-day trip to Crimea, the Georgian S.S.R. and the Armenian S.S.R., in the course of which four observatories would be visited and perhaps—with the luck of the weather gods—Mt. Elbrus, highest mountain of Europe might be glimpsed.

I found myself the only Britisher in a group of 18 astronomers. We represented six nationalities: a few from France, Belgium, Sweden, Germany and the majority from the U.S.A. of whom one had been born in Bulgaria, one in Bessarabia, one in Germany, one in Scandinavia and one in Great Britain—enough variety to make an interesting party. The man of senior position in our group was Dr. Minkowski of Mount Wilson and Palomar.

Leaving Moscow late on the evening of August 21 we flew south over the great grain growing collective farms of the Ukraine, and put down at the large city of Kharkov in the darkness of night and in pours of rain. After a three hour delay we continued southward. The dawn light showed vast fields and far spaced villages. Later in the morning we crossed the blue waters of the Gulf of Azov near the isthmus joining the Crimea to the mainland. We saw the long railway bridge and the large industrial city of Dzhankoi, skirted the low infertile eastern coast, then inland over rising land toward the mountains of the beautiful south coast region. Landing at Simferopol in a blaze of subtropical sunshine, we were transferred to a bus which rattled us over tortuous roads and up into the mountains with fine grey escarpments, many evergreen trees and also poplars, acacias, many kinds of nut trees, sycamores and rowans in abundance. About 10:30 a.m. we drew up at a mountain restaurant high above a beautiful rocky coastline. Here we had breakfast before driving for another hour and a half through mountain roads and down the hairpin bends to the beautiful harbour front of Yalta. This is a lovely little city spreading in terraces far up onto the hillsides, its esplanades lined with palms and flowering shrubs. A long grey stone mole and lighthouse guard

 1959

in hand. The explanation of this has been given in the remark of one character about to enter a North Star from a landing platform—"Look how high up we are already!"

In closing, may I quote again from the JOURNAL: "It is nothing short of thrilling to see the sun totally eclipsed, the black disk of the moon ringed with the rosy light of the chromosphere, studded perhaps by the Baily's Beads where sunlight still peeks through lunar valleys and the whole surrounded by the glorious pearly glow of the corona with pale streamers reaching out to distances of several solar diameters. No one who has seen this spectacle denies that it is worth waiting a lifetime to see—and not many people see it in their lifetime".

One small confession should be made—I have yet to see a total solar eclipse! I am hoping to be around in 1963 and perhaps free of the encumbrance of operating a spectrograph on board an aircraft at a high altitude.

(The documentary film "Operation Eclipse" was shown at the conclusion of this address.)

the harbour where the passenger ships and the smaller tramp ships of the Mediterranean and Black Seas lie at anchor or at the wharves. The famous white marble palace of the last Czar lies in beautiful grounds on a high rocky promontory overlooking the blue waters of the sea a few miles south of Yalta. It is now a sanatorium for non-chronic cases of tuberculosis. To get admission to it or similar places we were told by our interpreter that it was necessary to get not only a medical certificate of need but a letter of recommendation from the Trade Union official.

From Yalta we visited two fine research institutions, the Astrophysical Observatory of the Crimea 2,000 feet up on the high arid south central plateau and Semeis Observatory on the mountain slopes of the south coast. At the former we were shown the double astrographs, the large reflector (50-in.) for spectrographic work, the refractor with objective prism for radial-velocity determinations, a very short focus "stove pipe" telescope for work in the ultraviolet. We were taken to see the foundations being laid for a new telescope. Seven women were running the cement mixer and handling the wheel-barrows in the full blaze of the early afternoon sun. The temperature in the shade was 110°F.

Solar research was in progress in $H\alpha$ light with a vertical and in the K line with a horizontal set-up working in the 4th to the 8th order with resulting large dispersions. Radio astronomy is being developed vigorously at wave-lengths 1.5 m. and 10 cm. A special apparatus is in use for the study of atmospheric surges. A Mills Cross is planned for 21-cm. hydrogen research. In the courtyard of the main residence we sat down with our hosts to an abundant lunch with the wines of the country and luscious grapes and peaches.

At Semeis the following day we were seeing an institution founded in 1908 and known throughout the astronomical world for the work of its late director, Dr. Shajn, and for its great 41-in. refractor ordered originally by the Czar from the Grubb Parsons firm at Newcastle-on-Tyne. This lens was irreparably damaged when taken to Berlin by the German invaders in the second great war. Many of us had seen it lying chipped and scratched on the floor of a building at Pulkova Observatory. Dr. Shajn's office and portrait were shown to us and his great atlas of the diffuse nebulae. We examined the plates taken with their 60-cm. aperture meniscus telescope; their solar spectra and flare spectra. They took us to the brink of a hill where a plane mirror throws the light of nebulae down to a special spectrograph in the valley. We saw the aluminium-coated pyrex coelostat and the solar laboratory with its slits and grating. Observational conditions in the southern Crimea are excellent since the atmosphere is remarkably steady.

After much needed cool drinks and fruit we bade farewell to our genial hosts and descended by steep winding roads to the sea where a short walk brought us to a rocky beach with huge waves rolling in, beyond the hazard of which swimming in the swells was a life-restoring delight.

Late that evening we embarked on S.S. "Ukraina", going ashore next day on the east coast of the Black Sea at Novorossi, then Tuapsi where we visited the fruit market and saw nearly everyone carrying home melons, then Sochi a health resort town of lovely parks and fountains overlooking bathing beaches. The following morning at 5 a.m. we disembarked at Sukhumi, a thriving seaside resort backed by the foot-hills of the high Caucasus. Part of a large park is a monkey reserve attached to the Biological Centre of the Academy of Medical Sciences. A slow train journey through the great valleys between the northern rampart of the Caucasus and the less high southern range brought us through the town of Gori on the Kura River with a huge statue of its famous son Stalin on the station platform; and so to the capital of the Georgia S.S.R., Tbilisi (Tiflis). This is a city of 800,000, with many fine streets and public buildings on either side of the winding Kura River which flows south eastward 300 miles to the Caspian Sea. It is an historic city and with apparent pride the interpreter informed us that Christianity was brought up into south-east Europe through Tbilisi in the 4th century. We were shown extremely interesting 12th-century churches on 4th-century foundations, one now a museum, one still in use for Georgian Orthodox worship, and one in the care of a few pathetically poor nuns.

From Tbilisi we drove up the valley and high up mountain roads through pines, spruce and balsam to Abastumani Observatory, at altitude 5,300 feet in the southern Caucasus. Sixty years ago S. P. Glasenap had selected this site because of the remarkable transparency of the atmosphere but his dream of a great research observatory was not realized under the Czarist regime. Today this first of the Soviet mountain observatories is a hive of activity. We saw the 40-cm. Zeiss refractor with two 20-cm. cameras on the same mounting frequently used for objective prism work. A lunar electropolarimeter is sometimes used at the main focus of the large telescope. There are domes for a 30-cm. refractor; a 33-cm. reflector with fork type mounting for photoelectric work; a 44-cm. Schmidt used largely for Cepheid variables and for colour indices of extragalactic nebulae. Solar research includes work in $H\alpha$, the infrared, prominences and flares. A fourth building in this series is for problems of night glow in the visible, ultraviolet and infrared regions. The latest addition is a new Maksutov 70-cm. meniscus telescope with an 8° objective prism (the second largest known) giving stellar spectra down to 3,500 A. of 13th magnitude stars with 40-minute exposure.

Library, laboratories, staff house and a dining room are built under the pines. We were entertained at dinner from 3:30 p.m. to 5 p.m., then each given a bag of the finest Georgian fruit and a bottle of red Georgian wine for our long drive back to Tbilisi and a night train to Armenia.

In the darkness we came through the mountain passes and by daylight ran south very close by the carefully guarded Turkish frontier to the capital of this Socialist Soviet Republic, Erevan. It is situated on a high hot plateau. About fifty miles to the south on the Turkish side of the frontier rises a magnificent massive with Mt. Ararat's snow capped peak standing nearly 17,000 feet above sea level. From this prosperous little city of 400,000 (eleven times its population in 1917) we drove up 4,000 feet into the mountains to the Burakan Astrophysical Observatory, established in 1946 by the Armenian Academy of Sciences of the U.S.S.R. The Director is the distinguished Armenian scientist Dr. V. A. Ambartsumian. He and his staff conducted us around this impressive group of buildings where seven or eight telescopes are in operation, astrographs for two-colour plates of variable stars, a Schmidt instrument for research on stellar associations (a relatively new idea which had its birth at Burakan in 1947), a 21-in. Schmidt for colorimetric work on galaxies, a spectrograph for nebula studies and a 3-m. parabolic mirror for solar radiation of 50-cm. wave-length. As the sun was flooding the western slopes of Ararat with slanting golden light we went up to the site of the radio telescopes, three large flat aerials for study of discrete sources at wavelengths of 1.5 m. and 4.2 m. Other radio telescopes are under construction at a still higher altitude where a 1-m. Schmidt is also being erected.

Theoretical, statistical and observational work are in full flow at Burakan. One comment may be of interest about the equipment in the computation room—side by side with the computing machines is the abacus. The speed with which calculations are done on this simple apparatus is amazing. From Leningrad to Erevan we saw it in use in observatories, post offices, banks, shops and even in the markets.

That evening in the new Intourist Hotel in Erevan, the Director and his colleagues entertained us with true Armenian hospitality, informality and friendliness at a dinner at which innumerable toasts were proposed. We sat down at 9:30 p.m. and rose at midnight, said farewell to our hosts, packed our bags, slept for four hours and then were off to the airport. Mt. Ararat's snowy summit was touched softly by the "roseate fingers of dawn" as we winged our way northward on August 31. We passed over the lesser Caucasus, the great valley of the Kura, and the high Caucasus getting a splendid view of Mt. Elbrus towering snow clad to more than 18,000 feet; over the southern steppe land to Rostov airport on the delta of the Don and the Donets then off again over the vast collective farms of Ukraine and so by mid-afternoon to Moscow.

ASTRONOMY A CENTURY AGO

By A. Vibert Douglas
Queen's University, Kingston, Ontario

A book which is perhaps the first work on astronomy to be written in Canada appeared in 1862 from the press of Alexander Strachan and Co., London. The author was the fourth Principal of Queen's University, the Rev. William Leitch, D.D., "Principal and Primarius Professor of Theology, University of Queens' College, Canada". The runner-up to Dr. Caird for the Chair of Divinity at Glasgow, Dr. Leitch came to Canada in the year 1860 as the chosen successor to Principal Cook.

In his preface, the author states: "The object of the work is to present a survey of recent astronomical discovery and speculation, in connexion with the religious questions to which they give rise. These questions impart a new interest to astro-theology, and the present contribution is intended to meet, in some measure, the felt necessity of a better adjustment between the arguments of the theologian and the discoveries of the astronomer." With this object in view the author chose as his title *God's Glory in the Heavens*.

In the first of twenty chapters which cover 330 pages, we read that "the grand lesson of astronomy is that man's true dignity does not consist in the mere outward and physical. The more that the discoveries of astronomy make this world shrink into insignificance, the more amazing is the view of man's spiritual dignity." No opportunity is passed over to point out how every newly attained fact of astronomy displays afresh the glory of the Creator; the pages contain many such phrases as "the necessity of Divine contrivance", "Designing Intelligence", "the hand of Omnipotence", "Divine procedure", "Divine power", "the one great Architect".

Dr. Leitch was obsessed with the idea, so prevalent amongst thinking men in the middle of the last century, of the plurality of inhabited worlds. In his chapters on the moon, he dwells on the lack of atmosphere and extremes of temperature on the side visible to the earth, and then recounts "a recent discovery" which prevents us from ruling out the moon as a possible "theatre for the display of all the activities of animated and intelligent beings". The "discovery" he attributes to M. Hansen of Denmark working on Greenwich data supplied, he supposes, by the Astronomer Royal, Airy, namely that the moon's centre of gravity and centre of figure are 37 miles apart. If the hemisphere turned away from the earth is so much heavier than that facing the earth that air and water that a much smaller explosion might create a "hole" in the atmosphere through which almost vertically rising debris might be blown without much retardation. However if there is no concentration of the blast wave into a small solid angle, an atmospheric bulge rather than a "hole" would be produced. Also, fast moving particles would soon overtake the shock front as it expanded, cooled and slowed, and slower particles moving in the rarefied region behind the shock wave would not have the energy needed to rise to altitudes where the atmosphere is sufficiently attenuated to enable them to attain long ranges.

Particles sprayed backward into the direction of the incoming meteorite's track would presumably encounter a slightly longer region of rarefaction, but this could only last for a short time. As soon as the rebounding atmospheric pressure has built up to as much as one one-hundredth of its normal value, small bodies are quickly stopped by aerodynamic friction. Even if an incoming cosmic body could, by its primary shock wave, clear the atmosphere entirely from a path several tens of kilometres wide, the velocities of the heated air molecules at the boundaries of this rarefied region (and hence also the sonic speeds) may run to many kilometres per second. However, a rather rough calculation indicates that the downstream shockwave and turbulence in the wake of the meteorite would bring back the rarefied region to a density which would stop small tektites in less than one hundred kilometres. Only if the atmospheric density is reduced to one-thousandth or less of its normal value over the entire path, can the range approach intercontinental distances. Even if this could happen by some unspecified process, Chapman and Larson raise further objections on the basis that the heating effects caused by high-velocity flight through even an attenuated atmosphere are incompatible with those observed in tektites.

Hence it appears improbable that the small tektites forming the australite strewnfield could have been distributed in their present form by a meteoritic impact in Antarctica.

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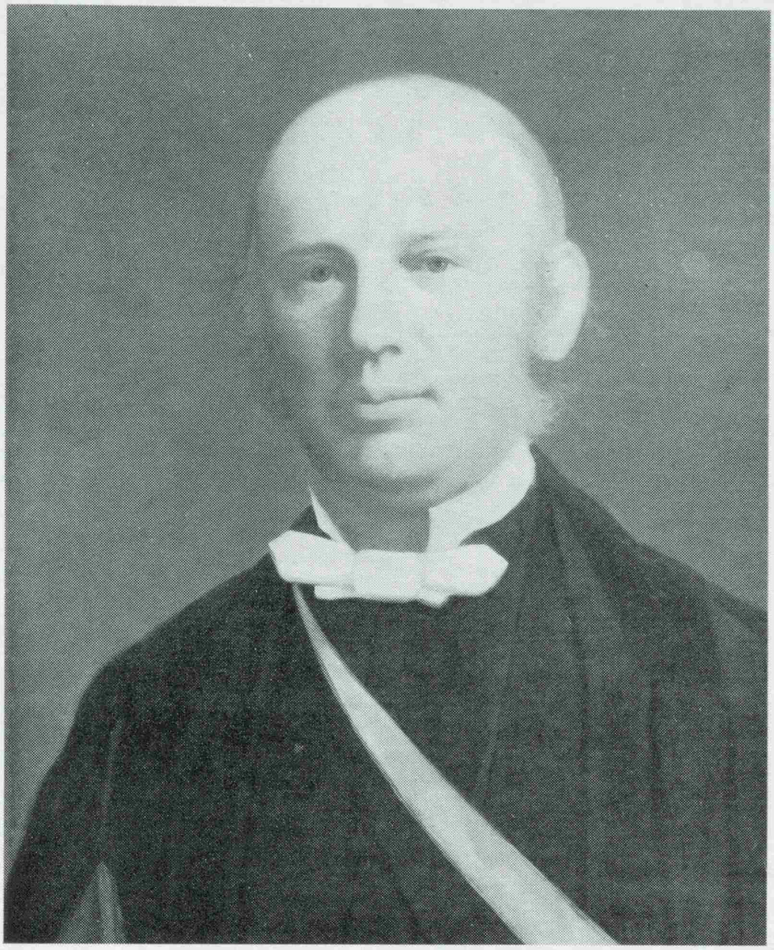

Rev. William Leitch, D.D., Principal of Queen's University, 1860–1864.

are held to it by the greater gravitational attraction, then life may exist here and a flourishing civilization may have developed. The author then lets his imagination take wings as he pictures an intrepid lunar explorer travelling to the limit of his inhabitable hemisphere and viewing with amazement this earth of ours coming into view on his horizon—"what a tale of wonder will the traveller have to tell, when, after his perilous adventures, he returns to the bosum of his family!" Our author tells us that this chapter was written in 1860.

The next chapter is entitled "The Discovery of the New Planet Vulcan".

Leverrier had informed the French Academy of Science in September 1859 that the unexplained motion of Mercury might be accounted for by the existence of a small planet between the sun and Mercury. In December of that year he received a letter from Dr. Lescarbault, physician in the little town of Orgères (Eure et Loire), informing him that nine months earlier he had observed a small planet crossing the disk of the sun. "The village-doctor humbly inquired of nature *what is*. The high priest of science had oracularly declared *what must be*." So writes Dr. Leitch and proceeds to quote the Abbé Moigno's account of Leverrier's visit to Orgères: "One would require to have seen M. Lescarbault, so simple, so modest, so timid, to comprehend the agitation with which he was seized, when the interrogator, drawing himself up to his full height, and with that brusque intonation, which he can assume when he pleases, said to him, with severe look, 'Is it you, sir, who pretend to have discovered the intra-mercurial planet? . . .' The lamb trembled all over at this rude summons of the lion; he tried to speak, but he only stammered out the following reply: 'At four o'clock on the 26th of March, faithful to my constant habit, I looked through my telescope and observed the disk of the sun, when, all at once, I detected near the eastern edge a small black point, perfectly round and sharply defined, passing across the disk with a very sensible motion. . . .' ." After some anxious searching the doctor found a square powder-paper and a board on both of which he had scribbled observations and calculations. He showed Leverrier his little telescope and his watch explaining how he subdivided the minutes by means of his own pulse beats. "The time had now come", says the Abbé Moigno, "for the lion to soften down, and to give heart to the trembling lamb. Leverrier did this with perfect grace—with a dignity full of kindness." Evidently convinced by the evidence given him, Leverrier published the "discovery" to the world , and the Emperor decorated the village-doctor with the order of the Legion of Honour. The period of Vulcan was said to be 19 days 17 hours.

In three chapters on the sun, the author discusses the then current argument as to whether the corona surrounds the sun or the moon. Father Secchi of the Vatican Observatory is quoted as favouring the latter but Dr. Leitch considers the arguments for the former are more cogent. The mystery of the red prominences is discussed and their possible connection with sun-spots, "funnels in the luminous envelope, through which inflammable gases rise, and are burned in the region of the corona or atmosphere, where they appear as red flames". The expectation that at the next total solar eclipse the limitations of the human eye will be replaced "by applying a sensitive photographic surface to the telescope" is hailed with enthusiasm.

Applied spectroscopy was a thrilling new line of research a hundred years ago. Bunsen and Kirchhoff were explaining the Fraunhofer lines in the solar spectrum and the chemistry of the sun was being revealed—iron, magnesium, chromium, sodium and nickel; but why not silver, copper, zinc, aluminium, cobalt and mercury "though they have very characteristic spectra"?

Comets provided a host of problems. The older people remembered the great comet of 1811, "spanning half the circuit of the heavens with its tail". Biela's comet attracted wide attention in 1846 and then came the great comet of 1858, Donati's, with its developing fan-like tail, its multiple envelopes causing international disputes as to the forces involved.

Chapters on the current knowledge of the planets lead up to the Nebular Hypothesis which "must be dealt with purely as a question of science . . . natural theology can only gain by the discovery of another wisely-adapted wheel in the celestial mechanism".

A brief discussion of stellar grouping is based largely on the work of Lord Rosse. Nebulae, of course, was then an inclusive term for "the ring nebula, the crab, the dumb-bell, and various forms of spiral nebulae". The resolution of the great nebula in Andromeda by Lord Rosse's telescope leads the astronomer "now to contemplate streams of bright suns hastening on along their spiral course to some unknown destiny". The attempted proof by Maedlar that "our firmament revolves round the bright star Alcyone in the Pleiades . . . is by no means satisfactory". Nevertheless in the Synoptical Tables at the end of his book, the author includes the item that the sun's distance from Alcyone, the centre of the stellar system (Maedlar) is 34,000,000 times the radius of the earth's orbit. In these Tables other items are of interest: in 1860 only the four Galilean satellites of Jupiter were known but eight of Saturn are recorded, four of Uranus and one of Neptune; the number of binary stars for which periods were known was 15; the number of planetary nebulae recorded was 25, of asteroids (1861) 71, and of periodic comets 27; the velocity of light was believed to be 192,000 miles a second.

In his final chapter, the author returns to the topic of the plurality of worlds. Are the other planets inhabited? Their similarities and dissimilarities to our earth are discussed and four types of argument are outlined. First, the "*a priori* argument" that because of the nature of God, the other planets must be inhabited—this he solemnly repudiates. Second, the "metaphysical argument" that where there are objects of sense, there must be sentient beings—this too he rejects as nonsense. Third, the argument from Scripture, by selecting passages here and there and drawing what he considers unjustifiable conclusions. Fourth, the "analogical or astronomical argument founded simply on the estimation of probabilities and independent of any genetic theories regarding the introduction of life". Considering the range of variation of terrestrial conditions within which life exists, he concludes that "the probability certainly is that some of the bodies of the system, such as Mars, Jupiter and Saturn, do not so far vary from the normal [earth] conditions as to render life improbable". Realizing that all bodies of the solar system are "in transition", the author points out that the favourable epoch for life on any one planet is unlikely to occur simultaneously on another.

Eleven pages at the close are given over to criticisms of the writings of Dr. Whewell, Master of Trinity College, Cambridge, of Thomas Paine, of Sir David Brewster of Edinburgh, and of Dr. Chalmers—in fact the book ends in a sermon on sin and redemption. "The universe is a great harp, and each orb a string in that harp; but one string, at least, is untuned. Sin has broken that string. . . . The whole universe felt the fall of man . . . the whole universe will feel the effects of redemption. . . . This world is no longer the *material* centre of the universe, but revelation teaches us that it is still the *spiritual* centre."

A strange book this is, when viewed in the light of knowledge and attitudes in 1964, and yet since it was published also in New York and ran to three editions by 1866, we must conclude that it spoke to its own times in accents which were understandable and stimulating. A theologian by training and vocation, Principal Leitch found in astronomy an intensely interesting hobby. On arrival at Queen's University he found Professor (Rev.) James Williamson in the chair of Mathematics and Natural Philosophy to which he had been appointed in 1842, and as Williamson was keenly interested and active in astronomy, he and Leitch together made the first careful determination of the longitude of Kingston. Their value was 76° 32′ 07″ which compares favourably with the subsequent geodetic survey value of 76° 28′ 12″. Knowing of this pioneer work in observational astronomy, we turn back with enhanced interest to Dr. Leitch's book wherein the theological mind dominates the presentation and the hand of an artist illustrates the work with delightful diagrams and drawings of many of the glories of the heavens.

The copy of this book, now housed in the Treasure Room of the Douglas Library of Queen's University, is inscribed on the fly leaf, "To the Library of Queen's College from the author, 1 Dec. 1862"; and on the title page facing a frontispiece showing drawings of what are obviously M51 and M33, is written, "Queen's College Library from the author".

ASTRONOMY AND McGILL UNIVERSITY

By A. Vibert Douglas

AT THE two hundred and fiftieth anniversary of the foundation of the Royal Observatory of Greenwich by Charles the Second, an event celebrated last summer at the close of the International Astronomical Conference, the growing interest in astronomy and the world-wide recognition of the importance of this branch of investigation, were emphasized by the Astronomer Royal in a speech in which he reviewed the great observatories of today in the order of their seniority.

The oldest existing observatory is that at the Vatican. Next in order are the 17th Century foundations, Leyden, Copenhagen, Paris, Greenwich. In the 18th Century came Prague, Geneva, Milan, Oxford, Rome, San Fernando, Madrid, Coimbra. But the 19th Century was unprecedented in this respect and witnessed the foundation in 1820 of Cambridge and Cape of Good Hope, in 1840 Harvard and Philadelphia, and then one after another of the great American Observatories.

In the short periods of their existence, the American Observatories have accumulated an immense amount of observational material and its discussion by men of marked ability has added very greatly to our knowledge of the Universe—the nature, distribution and motion of planets, satellites, stars and nebulae.

With such a spirit of keen astronomical research permeating the Universities of the United States, it is not to be wondered at that, more and more, astronomy is taking its place in the undergraduate and post-graduate curricula of the Universities and Colleges of the land. The writer was present last August at a round-table discussion on The Relation of the Astronomer to the Community, when Professor S. B. Barrett, of Yerkes Observatory, gave the opening paper and representatives of some ten different Colleges took part in the discussion. Apart from the definite courses in Astronomy and Astrophysics leading to degrees in these subjects and intended primarily as a training for those looking toward Astronomy as a profession, much stress was laid upon courses in general astronomy which form an integral part of the scheme of undergraduate education. One after another of the Professors from the American Colleges outlined the courses offered to their undergraduates, almost always including an optional non-mathematical course designed primarily to acquaint students with the outstanding facts of the Solar System and its relation to the Stellar Universe, and to give them some familiarity with the main constellations, and with the methods employed in the modern study of variable stars, binaries, clusters, and an introduction to stellar physics.

And then, suddenly, the writer was asked about Astronomy at McGill! What could be said? Little enough at best, but coming after the accounts of the Professors who had spoken, it seemed less still. The reply was something like this—There is, unfortunately, no full department of Astronomy at McGill. What Asstronomy is taught, is given as a half-session course (and a very good one) under the Mathematics Department, to honour students in Mathematics and Physics.

It is true that every McGill graduate may be proud of the work done at McGill for the entire Dominion in the matter of Time Signalling, but as far as providing for any teaching in Astronomy, McGill is far behind the American Universities. There is interest in Astronomy as is proved by the fact that a Montreal Centre of the Royal Astronomical Society of Canada is kept alive chiefly by the efforts of certain officers of instruction at McGill, though the society has no official connection with the University. Interest in Astrophysics is evidenced by the fact that four of the Graduate Colloquia in Physics were assigned to this topic during the last two years, and indeed the physics of the stars is throwing so much light upon some aspects of terrestrial physics, that no Department of Physics can afford to ignore it.

It is not always that a keen scientist who is in the forefront of research is much interested in the popularization of his subject—the dissemination of his knowledge to the undergraduate and to the general public; but there are great examples of men of science who, realizing their obligation to the community, have been enthusiastic supporters of every effort to pass on to others something at least of the broader outlook which they have helped to unfold. Both the Director of Yerkes Observatory and the Director of Harvard College Observatory are men of this class, inspiring lecturers, enthusiastic passers-on of the gems of thought which they garner from the skies. Each has spoken to the writer of the immense value he sets upon Astronomy in the schools and colleges as a means of awakening the imagination of youth, of uplifting their thoughts above and beyond petty things, of stimulating their interest in Nature and training their powers of logical thought. This spirit will spread in Canada as it is doing in the United States, and the obligation of training teachers to meet this need falls on our Universities today.

Canada's two Observatories are not the product of her Universities, but are Government Institutions—the Dominion Observatory, Ottawa, and the Dominion Astrophysical Observatory, Victoria, B.C.—institutions which are placing Canada second to none in regard to the quality, though, of course, not in the quantity, of her Astronomical and Astrophysical research. Canada's Universities must shoulder the responsibility of training men to carry on this work. Thus far the University of Toronto has borne this burden alone, and they can point with pride to a number of astronomers who received their preliminary training within the walls of Toronto University.

Surely it is time that the oldest University in our land ceased practically to ignore the oldest of the sciences—for man began to study the heavens from the time that he first straightened his spine and turned his face upward toward the light. Though venerable in its age, Astronomy is perenially young, and no science is today stepping out with greater vigour into realms yet unconquered than is Astrophysics. Furthermore, McGill University has received assurance from the Dominion Observatory, Ottawa, that they would gladly co-operate in a scheme whereby training in general astronomy, celestial mechanics and astrophysics would be given at McGill and practical training in observational astronomy given during the summer months at the Dominion Observatory. Such an arrangement could not be otherthan mutually beneficial, strengthening bonds already formed between the University and the Dominion Civil Service.

One of the best known and internationally respected astronomers of California told the writer a year or so ago that in the western States, McGill University was regarded as the Cambridge of North America. The Cambridge of North America! What a tribute to her Past—but what a challenge to her Present and her Future!

Cambridge has its traditions of Newton, Herschel, Adams, Darwin and now Newall, Eddington, Jeans and Milne in astronomy, and Newton, Stokes, Maxwell, Raleigh, and now Thomson, Wilson, Rutherford, Aston in Physics; and McGill in its 105 years can point to great thinkers, pioneer scientists, Fellows of the Royal Society, an Isaac Newton Scholar—men who have probed the mysteries of earth, air and water, the scattering of light, the tides, the atom—but can anyone picture the Cambridge of North America without a Department of Astronomy?

Can our University hope to merit that title in the eyes of her Southern co-workers in education and research if she fall so far behind them in the matter of Astronomy. Living Powers of the Present, make the McGill of today and the McGill of tomorrow worthy to be deemed The Cambridge of North America! Shades of the Departed, rise up and point the way!

With compliments
A.V.D.

ASTRONOMY AND THE ORPHIC HYMNS

By A. Vibert Douglas
Kingston Centre

A remarkably interesting piece of scholarly research has been done by Dr. Constantin S. Chassapis, astronomer at the Penteli Astronomical Station in Athens. After reading the copy of this paper sent to me by the author, it has become evident that many of our ideas of the historical development of astronomy will need to be revised in the light of Dr. Chassapis's findings.

First consider the date of the Orphic Hymns. Internal evidence of an astronomical nature places the hymns between 1841 B.C. and 1366 B.C. Evidence for the later date is based on a line which states that the winter and summer seasons were of equal duration. In the year 1968, the interval from spring to autumn equinoxes is 186d 10h and from autumn to spring equinoxes is 179d 14h, giving a difference of 6d 20h. Of course, this is due in part to precession of the earth's orbit, the summer solstice now coming within eleven days of aphelion, when the earth is travelling most slowly in its elliptic orbit. About 1366 B.C. the summer solstice would have occurred when the earth was near one end of the minor axis of its orbit, thus causing the symmetrical division of the seasons referred to in hymn 33, line 31. A line in hymn 26 refers to the spring equinox in Taurus and in hymn 13 the summer solstice in Leo; these positions indicate a limiting date of 1841 B.C. Hence the hymns belong to the period between these two dates. The author suggests the 17th century B.C. when the spring equinoctial point had not yet reached the faint stars of Aries and the two seasons differed by only about 6 hours.

Dr. Chassapis interprets lines in hymn 33 as evidence that "the Greeks in Orphic times had conceived the heliocentric idea and it was from them that it was later borrowed by Pythagoreans and Aristarchus. . . . Indeed they were aware of the sphericity and rotation of the earth. . . ." The word employed means "globe" and they divided it into torrid, temperate and frigid zones. The hymn suggests, however, that the earth was the centre of the celestial sphere which turned on an axis coincident with the axis of the earth. From hymn 7 it is deduced that the four seasons are due to the movement of the earth around the sun, the sun exerting the controlling influence.

The following conclusions are also drawn from the hymns by Dr. Chassapis in his 88-page paper:

 (1968)

The Orphics distinguished between the stars and the seven planets. They used the names in use today, which, it is claimed, are therefore of Orphic origin. They introduced the Zodiac, naming its 12 constellations and some others. These names are deemed to be of Orphic origin. They determined and named the ecliptic, using the same word employed by Archimedes centuries later. They developed astrology, Angaeus being an astrologer-astronomer. They knew that the diffused light, as well as that of dawn and twilight, were due to the atmosphere. They introduced the idea of the ether as filling the space beyond the atmosphere. They accepted the presence of mountains on the moon. They used a lunar calendar, the month being the interval between two full moons. They accepted that all phenomena were governed by universal law, which regulates all of the sky and earth and secures the stability of the existence of the earth. From the *Lithika* it appears that they were familiar with lenses.

The summary of this remarkable paper concludes thus:

(a) the existing views of the history of astronomy, concerning the so-called priority of the Assyro-Babylonians over the Greeks for many of the above ideas, must be revised.

(b) the views of pre-history, according to which the pre-Greeks and the Aegians were not Greek tribes, must be revised. The dating of the Orphic Hymns through astronomical methods proves that these, regardless of the time of their gathering and registration during the 6th century B.C., were formulated much earlier and were communicated from generation to generation by the initiated of Orphism. These hymns were the genuine product of the Greeks who lived in the country in the depths of the 2nd millenium B.C. They cultivated the observation of the sky, and laid the foundations of the basic astronomical truths.

I am happy to express my gratitude to Dr. C. S. Chassapis for this paper and hope it may call forth valuable comment from other scholars who are competent in these two fields—early Greek literature and astronomy.

ASTRONOMY IN A WORLD AT WAR

BY

A. VIBERT DOUGLAS

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ASTRONOMY IN A WORLD AT WAR

By A. Vibert Douglas

(THE ADDRESS OF THE PRESIDENT OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA)

I

SCIENCE has advanced during the last four years both because and in spite of war. Some of the sciences have made tremendous strides as a direct result of the challenge of war necessities. Physics, chemistry, metallurgy, and all the branches of medical science are in this category; some day the full story of their great achievements may be made known. Other branches of knowledge, while far from being unaffected by the war, have continued to advance largely in spite of the upheavals in the life of nations and individuals which world war inevitably brings. Astronomy is in this latter class.

Astronomy and astronomers are playing an important part in the war chiefly along the two lines which have always presented fundamentally stellar problems—direction and time. But the main advances in astronomy in these last four years have been made in spite of the war. It is right and fitting and indeed very encouraging that this is the case. When so much that is of intrinsic beauty and of fundamental value is being destroyed by war, and when so many worthwhile activities have to cease, it is good indeed to know that there are astronomers on this continent, and even in some parts of Europe, and in Australia, Africa, India, and probably in Japan, who are able to carry on the continuity of observations on stars and starlight, sun and moon, planets and asteroids, comets and meteors.

If the continuity of observation in many branches of astronomical work were to be completely broken, it would be an irreparable loss to science. Thus it is with satisfaction and great admiration that we read in the Reports of the Royal Observatory, Greenwich, that damage done by enemy action to one of the buildings and to the Airy transit circle has been largely made good, and observations recommenced with that instrument upon Sun, Venus and the stars in the clock and azimuth lists; that parallax determinations are going on; that solar photography and observations of chromospheric eruptions in Hα are continuing; and that the two Time Service Stations have operated continuously. During this period the exhaustive work on the Solar Parallax was brought to completion.

In France solar, planetary and stellar research have been carried on, and in Holland galactic problems, long period variables, dark nebulosity and theoretical astrophysics have been under investigation even in these tragic years. In the U.S.S.R. where at least one observatory has been destroyed and another dismantled, plans are already made for resumption of activity and for the erection of a new observatory to further the study of latitude variations. From two observatories east of the farthest battle front we know that papers have been published recently on photo-electric calorimetry and on colour temperatures.

Similar records of observations and measurements carried on despite air raids, despite reduction of staff, despite pressing war problems and difficulties of all kinds, could be quoted from many observatories in countries deeply involved in fighting for their very existence.

In these and in countries like our own,—at war, but far removed from the main theatres of conflict—there has been a very important contribution made by astronomers in the adaptation of astronomical observations and calculations to the problems of air navigation. The Director of the Glasgow University Observatory, Professor W. M. Smart, has produced three books on Nautical Astronomy since this War began, and under his instruction, R.A.F. pilots and cadets are learning the art and science of navigation. Scores of astronomers, including Canadian men well known to many of us, are doing similar work, giving all their time, skill

and energy, and often risking their lives in the air with student pilots, in order to impart this so necessary instruction in air navigation.

In the Koran, it is written: "God has given you the stars to be guides in the dark, both by land and sea." Homer tells of Ulysses on his raft that he sat at the helm and "marked the skies, nor closed in sleep his ever watchful eyes." But navigation from the back of a camel or from the bridge of a ship can be a relatively leisurely performance. Not so in a modern airplane! The navigator takes a sight on a star or planet, he reads his chronometer, and then if his calculations take him five minutes to perform, he and his plane are already perhaps twenty-five miles away from the ascertained position. Every minute that astronomers have been able to cut off the time for computation of position is of the greatest value to airmen flying over seven seas and six continents, across enemy lines, with objectives a mere dot on the map—a railway yard, a factory, an airfield.

II

Turning to the subject of time measurement, it is worthy of note that during these war years an accuracy never before dreamed of has been attained. It was in April 1938, that Essen described before the Royal Astronomical Society of London, the researches at the National Physical Laboratory which had resulted in the new quartz clock, of which so much was hoped. This clock makes use of the properties of the crystal oscillator, one of the most reliable and perfect mechanical systems known to man. Essen describes quartz clocks briefly as "consisting of phonic motors controlled via frequency dividers by vibrating quartz crystals." In a paper presented to the Royal Astronomical Society last June, Greaves and Symms record the intercomparisons of three Greenwich free pendulum Shortt clocks, two National Physical Laboratory quartz clocks, and three quartz clocks at the Post Office Radio Branch Laboratories.

They analyze clock errors into three classes (a) erratic variations in phase, (b) erratic variations in rate, (c) a combination of phase and rate variations, producing a cumulative effect. They show that two Shortt clocks and two quartz clocks may indicate approximately the same mean absolute second differences of relative clock error, but the distribution of errors between the three classes is different—the quartz clocks show very little error of (b) and (c) relative to Shortt clocks, and errors of class (a) do not affect the long-period performance of a clock.

The famous Shortt clocks are now known to be incapable of giving the precision demanded, but the Astronomer Royal hastened to pay them a deserved tribute:

> Twenty years ago we had several papers dealing with the performance of the Shortt clocks, then looked upon with great expectations. In this clock was achieved in a simple and beautiful manner what horologists had been striving after for years, namely, a pendulum designed solely for the purpose of beating time whilst being called upon to perform no mechanical work. But if the subsequent performance of this type of clock did not fully come up to our high expectations, the Shortt Free Pendulum has one thing to its everlasting credit—it forced the astronomers to adopt the use of Mean Sidereal Time where formerly True Sidereal Time had been adequate. During the intervening twenty years since this type of clock was installed in many observatories, new requirements have sprung up. In the past the main purpose of a time service was to provide absolute time with an accuracy sufficient for navigational and surveying requirements. But the new use of frequency standards has raised a demand for 24-hour intervals correct to the very high accuracy of a millisecond.
>
> It will be seen then that as absolute standards at Greenwich, Shortt clocks have become obsolete. Our long-range predictions are now based entirely on quartz clocks, free pendulum clocks being used only for extrapolation over an interval of 24 hours.

III

Let us turn our thoughts to cosmology and recall that it was during the first World War that Einstein's general theory of relativity appeared. Two years later, in the war year 1917, came the first suggestion of an expanding universe. This was one interpretation of de Sitter's modification of Einstein's cosmology, implying as it did red shifts of the spectrum lines of faint distant objects. Incidentally, we may turn aside to remark that while de Sitter was then working in a Holland that had been allowed to remain neutral, his spirit is living on in the occupied and battered Holland of this war, and he, though dead, yet speaketh, inspiring his successors at Leiden and Amsterdam to carry on the tradition of astrophysical research in spite of all external difficulties—thus Verweij has produced a theoretical discussion of Stark effect in stellar spectra

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De Sitter had also deduced from Einstein's theory the four conclusions which offered a hope of observational confirmation. One of these four crucial tests was whether radiant energy passing close to a body with an intense gravitational field surrounding it, would be deflected in accordance with Newton's law of gravitation or with Einstein's modification of that law. It was Professor A. S. Eddington who realized the great importance of making this test at the first favourable opportunity, namely, at the time of the total solar eclipse which was to occur on May 29th, 1919, with the Hyades as background. War or no war, all the plans and preparations were pushed ahead and thus it was that when the eventful day arrived, even though the Treaty of Versailles had not yet been signed, two British expeditions were in readiness to take the crucial photographs. I often reread the passage written by a learned mathematician and philosopher in which he described the meeting of the Royal Society when the results of these eclipse expeditions were announced, verifying as they did the theory of Einstein:

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elements up to but not heavier than neon may in these ways be synthesized.

If the central regions of the hottest stars are not the crucibles of nature wherein the eighty-two heavier elements are built up, where and under what conditions were they formed? A highly speculative answer is to be formed in an intensely interesting piece of theoretical research carried out during the early years of this war by Chandrasekhar and Heinrich. They have been inquiring under what conditions of nature the basic units of matter—electrons, protons, neutrons, positrons—could be expected to come together to form, in their various proportions, the atoms of all the isotopes of the elements familiar to the chemist. As these elements compose all stellar bodies as well as all things terrestrial, their synthesis is a cosmic problem. They find that such tremendous extremes of high temperature and high density would be required that it is necessary to suppose that all the matter of the known universe was once confined to a volume of radius only about twenty times that of the solar system. Such a sphere drawn around our sun as centre does not now contain a single other star. Yet into such a volume there may once have been packed not only all the thousand million stars of our own galaxy, but all the millions of other galaxies. This is indeed a picture reminiscent of the "giant molecule" of Lemaître. Since stars and galaxies are not now thus packed, expansion must have taken place some time very long ago. The present rate of expansion is such that galactic distances are doubled every 1800 million years. This gives the time elapsed, since the expansion began, as several thousand million years which is in satisfactory accord with the age of the earth as determined by other physical lines of approach and regarded necessarily as a lower limit for the age of the universe.

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VI

The numbers 136, 137, 256 will awaken in the minds of many of you memories of a kindled interest, of perplexity, doubt, expectation and perhaps of moments of great thrill, as you think back over the last ten years. One name alone stands central amongst these memories—that of Sir A. S. Eddington. This has been his playground pre-eminently. Some of us have stood fascinated at the edge of the field watching this illusive game played patiently, skillfully, brilliantly by one man, a master juggler with the elements of the theory of groups, with quantum mechanics, and with the basic units of measurement, producing, as from the proverbial hat, physical constants both atomic and astronomical. Some there have been who paused to watch briefly, to smile or even ridicule the Aristotelian *tour de force*. But steadily and doggedly the theory has been pushed forward, several papers having appeared in the last three years until now the evidence is overwhelmingly great that, with no observational data other than three basic constants, namely, the velocity of light and the Rydberg and Faraday constants for hydrogen, it is possible to calculate theoretically the following thirteen physical constants: charge e; Planck's constant; masses of electron, proton, hydrogen atom; gravitation constant; fine structure constant; nuclear range-constant; nuclear energy-constant; mass of universe; number of particles in universe; Einstein radius of space; nebular speed. This is a striking achievement.

Let us look briefly at just two of these constants. The recessional velocity of the spiral nebulae is calculated to be 572.36 km per second per megaparsec. The observational value of Hubble and Humason is 560. When the great 200-inch reflector comes into action, we shall expect to see the observational value come closer to Eddington's determination.

The number of independent quadruple wave functions at any point is $2 \times 136 \times 2^{256}$ or 3.15×10^{79} and in his earlier work Eddington identified this with the number of particles in the universe. Since 1939 he has found that a question of non-integrability in spherical space necessitates a reduction of 25 per cent; so the number given in his 1942 paper is 2.36×10^{79}.

This theoretical approach has now reached a point where its author can write "I think the theory now deserves to be the accepted theory—my definition of an 'accepted theory' being that it is the theory which is so far right that everyone is interested in trying to discover what is wrong with it." Can we wonder that he

pauses in his work to refer to "the devastating beauty of quantum arithmetic." This entire investigation must surely rank as one of the great adventures of the human mind exemplifying Blake's stately metaphor—"Imagination goes forth in its uncurbed glory."

VII

This brief survey of a few fields of astronomical research, incomplete as it obviously is, will serve nevertheless to indicate that pure science is not dormant, much less is it dead, during the terrible years when the vile demoniacal God of War stands astride the earth. For many years the International Astronomical Union has been an influence for understanding, and for co-operation in the search for knowledge with mutual respect and trust. It is once again temporarily in abeyance, and it will once again rise to carry on it's good work. The lesson of astronomy down the centuries has been one of international interdependence and mutual indebtedness.

The problems facing mankind are very complex,—the dealings of man with man, the attitude of nation to nation. No solutions making for international good will and world peace will be achieved by men of narrow mind, myopic sight and dwarfed soul. The far vision in time and space, the winged imagination that leaps the barrier of here and now—these are the qualities of mind and spirit needed in every walk of life and needed superlatively in the leaders of every nation if in the years just ahead of us progress is to be made towards the great ideal of international unity. How can the eyes of the blind be awakened to the dazzling vision of the City of God? For some it may be by the contagious enthusiasm of a great teacher or leader, for others the illumination from poetry, for some the spark is kindled by the study of history, or of philosophy, and for yet others it is through natural philosophy and astronomy. Mankind needs the perspective of the cosmic background. "The great values," said Field Marshal Smuts, "retain their unfading glory and derive new meaning from a cosmic setting."

There is a challenge to the scientists and to the lovers of science to teach the boys and girls, the young men and women of today and tomorrow, the ideals, the aims, the methods and the integrity of the scientific approach to facts and to problems.

We do not forget the dictum of Rabelais, "Science without conscience is damnation." Wartime drives this home with bitter and tragic intensity. But we may say with great assurance that Science with conscience has an essential part to play in procuring and maintaining world conditions in which peace can endure.

All who have the ideal of world-citizenship at heart, all who have the far vision of things that have been and of things that may be, and the realistic grasp of things that are, must cooperate in the great task of bringing into the affairs of mankind upon this earth some semblance of the order, beauty and harmony of the universe of stars. Towards this end, both directly and indirectly, astronomy and astronomers can play a part; and it may prove to be a part which no one else can play for them because they, the astronomers, are the people with the fullest understanding of the cosmic background.

A. Vibert Douglas

Queen's University
Kingston, Ontario.
Jan. 21, 1944.

A V Douglas

ASTRONOMY IN A WORLD AT WAR

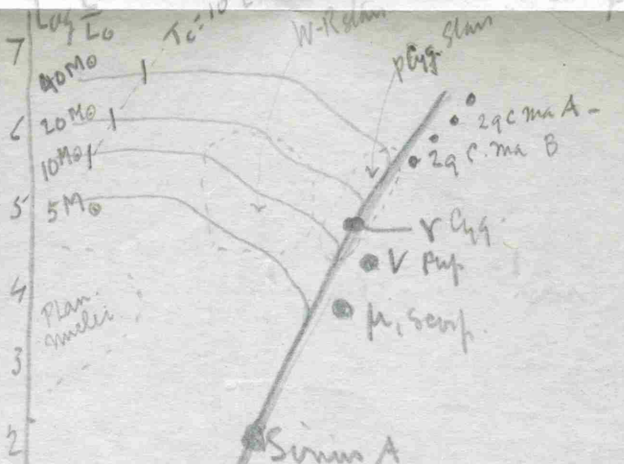
with refs. Gamow & Bethe

BY

A. Vibert Douglas

Reprinted from
The Journal of the Royal Astronomical Society of Canada
March, 1944

Central temp up to 10^9 C. threshold for so-called Urca-processes by which a large no of neutrinos can be produced in stellar interior. Escaping thro body of star these carry away the heat energy of central regions. at rate 10^{10} or even 10^{15} erg/g. sec. Thus neutrinos act as a thermostatic arrangement preventing centre of star rising much above 10^9 °C. Contraction continues + goes over into a major collapse at values of $\log \frac{R}{R_0}$ greater for more luminous stars. See fig. 4 p. 25.



Symmetrical collapse not likely

Polar regions collapse

Conclude that in contrast to the mass ejection by a W-R star, by nuclei of planetary neb + possibly by ordinary novae the explosion of a Super nova is of a more mechanical character + is directly connected with dynamical peculiarities of a collapse process.

Baade calcs for Chinese Supernova 1054 vel of gases 1000 km/sec + total mass of gas shell may be 15 × suns mass. This alone unless central energy producing matter is also ejected will not account for tremendous luminosity of super novae. Hence conclusion above.

Phys. Rev. 65. Jan 1 + 15 –
1944

G. Gamow

Evoln. of Contracting Stars.

p. 20 — 32.

Excellent material

Energy-producing shell
Red Giants.
W – R
Collapse – at polar region
with equatorial ejection

Neutrinos generated in Urca-region
& carry off Grav. energy of collapse

over.

Gamow.

Neutrino theory of stellar Collapse — novae + super n
diff of mass gives
diff in n or super n –
Gamow – Phys Rev 1941. April

Free electrons + O nuclei react to produce neutrino losses leading to complete collapse in $\frac{1}{2}$ hr.

Gamow

Nuclear Reactions in Stellar Ev. Nature Sept 30 + Oct 7 1939

^{12}C + ^{14}N catalysts in C. cycle main sequence.
non cyclical — ^{10}B cluster variables
^{6}Li ^{7}Li ^{9}Be ^{11}B for Cepheids
^{2}H + ^{3}H for long p. variables
a light star becomes degenerate & white dwarf.
A heavy star will eventually collapse to neutron core with immense liberation of grav. energy.

ASTRONOMY IN A WORLD AT WAR

By A. Vibert Douglas

(The Address of the President of the Royal Astronomical Society of Canada)

I

Science has advanced during the last four years both because and in spite of war. Some of the sciences have made tremendous strides as a direct result of the challenge of war necessities. Physics, chemistry, metallurgy, and all the branches of medical science are in this category; some day the full story of their great achievements may be made known. Other branches of knowledge, while far from being unaffected by the war, have continued to advance largely in spite of the upheavals in the life of nations and individuals which world war inevitably brings. Astronomy is in this latter class.

Three

Astronomy and astronomers are playing an important part in the war chiefly along the two lines which have always presented fundamentally stellar problems—direction and time. But the main advances in astronomy in these last four years have been made in spite of the war. It is right and fitting and indeed very encouraging that this is the case. When so much that is of intrinsic beauty and of fundamental value is being destroyed by war, and when so many worthwhile activities have to cease, it is good indeed to know that there are astronomers on this continent, and even in some parts of Europe, and in Australia, Africa, India, and probably in Japan, who are able to carry on the continuity of observations on stars and starlight, sun and moon, planets and asteroids, comets and meteors.

If the continuity of observation in many branches of astronomical work were to be completely broken, it would be an irreparable loss to science. Thus it is with satisfaction and great admiration that we read in the Reports of the Royal Observatory, Greenwich, that damage done by enemy action to one of the buildings and to the Airy transit circle has been largely made good, and observations recommenced with that instrument upon Sun, Venus and the stars in the clock and azimuth lists; that parallax determinations are going on; that solar photography and observations of chromospheric eruptions in Hα are continuing; and that the two Time Service Stations have operated continuously. During this period the exhaustive work on the Solar Parallax was brought to completion.

In France solar, planetary and stellar research have been carried on, and in Holland galactic problems, long period variables, dark nebulosity and theoretical astrophysics have been under investigation even in these tragic years. In the U.S.S.R. where at least [redacted] observatory has been destroyed ~~and another dismantled~~, plans are already made for resumption of activity and for the erection of [redacted] new observatory to further the study of latitude variations. From two observatories east of the farthest battle front we know that papers have been published recently on photo-electric calorimetry and on colour temperatures.

Similar records of observations and measurements carried on despite air raids, despite reduction of staff, despite pressing war problems and difficulties of all kinds, could be quoted from many observatories in countries deeply involved in fighting for their very existence.

In these and in countries like our own,—at war, but far removed from the main theatres of conflict—there has been a very important contribution made by astronomers in the adaptation of astronomical observations and calculations to the problems of air navigation. The Director of the Glasgow University Observatory, ~~Professor~~ W. M. Smart, has produced three books on Nautical Astronomy since this War began, and under his instruction, R.A.F. pilots and cadets are learning the art and science of navigation. Scores of astronomers, including Canadian men well known to many of us, are doing similar work, giving all their time, skill

and energy, and often risking their lives in the air with student pilots, in order to impart this so necessary instruction in air navigation.

In the Koran, it is written: "God has given you the stars to be guides in the dark, both by land and sea." Homer tells of Ulysses on his raft that he sat at the helm and "marked the skies, nor closed in sleep his ever watchful eyes." But navigation from the back of a camel or from the bridge of a ship can be a relatively leisurely performance. Not so in a modern airplane! The navigator takes a sight on a star or planet, he reads his chronometer, and then if his calculations take him five minutes to perform, he and his plane are already perhaps twenty-five miles away from the ascertained position. Every minute that astronomers have been able to cut off the time for computation of position is of the greatest value to airmen flying over seven seas and six continents, across enemy lines, with objectives a mere dot on the map—a railway yard, a factory, an airfield.

II

Turning to the subject of time measurement, it is worthy of note that during these war years an accuracy never before dreamed of has been attained. It was in April 1938, that Essen described before the Royal Astronomical Society ~~of London~~, the researches at the National Physical Laboratory which had resulted in the new quartz clock, of which so much was hoped. This clock makes use of the properties of the crystal oscillator, one of the most reliable and perfect mechanical systems known to man. Essen describes quartz clocks briefly as "consisting of phonic motors controlled via frequency dividers by vibrating quartz crystals." In a paper presented to the Royal Astronomical Society last June, Greaves and Symms record the intercomparisons of three Greenwich free pendulum Shortt clocks, two National Physical Laboratory quartz clocks, and three quartz clocks at the Post Office Radio Branch Laboratories.

They analyze clock errors into three classes (a) erratic variations in phase, (b) erratic variations in rate, (c) a combination of phase and rate variations, producing a cumulative effect. They show that two Shortt clocks and two quartz clocks may indicate approximately the same mean absolute second differences of relative clock error, but the distribution of errors between the three classes is different—the quartz clocks show very little error of (b) and (c) relative to Shortt clocks, and errors of class (a) do not affect the long-period performance of a clock.

The famous Shortt clocks are now known to be incapable of giving the precision demanded, but the Astronomer Royal hastened to pay them a deserved tribute:

> Twenty years ago we had several papers dealing with the performance of the Shortt clocks, then looked upon with great expectations. In this clock was achieved in a simple and beautiful manner what horologists had been striving after for years, namely, a pendulum designed solely for the purpose of beating time whilst being called upon to perform no mechanical work. But if the subsequent performance of this type of clock did not fully come up to our high expectations, the Shortt Free Pendulum has one thing to its everlasting credit—it forced the astronomers to adopt the use of Mean Sidereal Time where formerly True Sidereal Time had been adequate. During the intervening twenty years since this type of clock was installed in many observatories, new requirements have sprung up. In the past the main purpose of a time service was to provide absolute time with an accuracy sufficient for navigational and surveying requirements. But the new use of frequency standards has raised a demand for 24-hour intervals correct to the very high accuracy of a millisecond.
>
> It will be seen then that as absolute standards at Greenwich, Shortt clocks have become obsolete. Our long-range predictions are now based entirely on quartz clocks, free pendulum clocks being used only for extrapolation over an interval of 24 hours.

III

Let us turn our thoughts to cosmology and recall that it was during the first World War that Einstein's general theory of relativity appeared. Two years later, in the war year 1917, came the first suggestion of an expanding universe. This was one interpretation of de Sitter's modification of Einstein's cosmology, implying as it did red shifts of the spectrum lines of faint distant objects. Incidentally, we may turn aside to remark that while de Sitter was then working in a Holland that had been allowed to remain neutral, his spirit is living on in the occupied and battered Holland of this war, and he, though dead, yet speaketh, inspiring his successors at Leiden and Amsterdam to carry on the tradition of astrophysical research in spite of all external difficulties—thus Verweij has produced a theoretical discussion of Stark effect in stellar spectra

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Ten years later, Lemaître, who had fought with the Belgian army in the war years and afterwards entered Louvain University, brought forward his theory of expanding space. This made the radius of curvature of space a function of time, and gave a new stimulus to the astronomers in those great observatories equipped to probe most deeply into space. In the following years, at Mt. Wilson and Harvard particularly, the exploration of space was carried on with vigour, and methods were found of estimating the distances of the remote galaxies. A special lens was designed to obtain their spectra at Mt. Wilson, and thanks to the broad strong H and K lines of ionized calcium, red shifts could be measured to distances estimated as 250,000,000 light years. The correlation between distance and red shift has provided a remarkable confirmation of the theory of the expanding universe. Recessional velocities up to one seventh the velocity of light have now been observed. In the years between the wars a few voices were heard to question the interpretation of the red shift as a Doppler displacement, but since no alternative explanation suggested itself without postulating some entirely new law of Nature, the expanding universe remained as a working hypothesis in the background of most astronomers' minds.

One of the interesting things that these recent war years have brought is the reopening of this question by E. P. Hubble. Is the universe expanding? Is the red shift actually indicative of motion? Or is the framework of the universe static? And if static, what is the explanation of the displacement of all spectrum lines to the red for distant galaxies? Hubble's analysis of all available data based on the assumption that the universe is expanding, necessitates the calculation of a dimming factor due to recession. When correction is made for this in the estimation of distances, he claims that a map results which is not of homogeneous density, which implies an increasing rate of expansion with distance, and therefore an "age" of the Universe totally inadequate. On the other hand when he assumes a static framework for the universe, the analysis of all the data gives a map that shows a linear relation between red shift and distance, and a homogeneity of density. This map has more to commend it than has the former map, and hence the assumption of a static framework appears to be favoured. But, as

various astronomers have pointed out, the weakness of this result lies in the large probable errors of the quantities involved, so that even an apparent divergence of 30 per cent from uniformity of density is not evidence weighty or certain enough to overthrow the Lemaître theory of an expanding universe.

IV

Important advances have been made recently in our understanding of the sources of energy within stars which permit them to radiate energy as they do. Bethe has given an exposition of a cyclical sequence of atomic changes and interactions whose net result leaves a star with fewer hydrogen atoms, but with more helium and the liberation of excess nuclear energy in the form of gamma rays. This is now generally referred to as the carbon cycle and it is too beautiful not to be recorded here, for though published a few months before the war, it has been during the war years that it has become a part of astronomical thinking. Of the six stages, four result from collisions with hydrogen atoms in the deep hot interiors of main sequence stars, and two are spontaneous disintegrations of unstable nuclei.

1. $C^{12} + H^1 = N^{13} + \gamma$
2. $N^{13} \longrightarrow C^{13} +$ positron
3. $C^{13} + H^1 = N^{14} + \gamma$
4. $N^{14} + H^1 = O^{15} + \gamma$
5. $O^{15} \longrightarrow N^{15} +$ positron
6. $N^{15} + H^1 = C^{12} + He^4$

The two positrons rapidly interact with electrons to give rise to gamma radiation. Thus is produced the penetrating radiation, most of which in the course of its progress towards the boundary of the star becomes transformed into the heat, light and ultra violet radiation that pour out from the photosphere. The central temperatures of the cool giant stars are insufficient to maintain this active cycle, but theory can also explain their radiant energy in terms of atomic collisions and transmutations which are, however non cyclical. Hydrogen, deuterium, lithium, beryllium, boron are slowly transformed into helium, and so on. It appears that elements up to but not heavier than neon may in these ways be synthesized.

If the central regions of the hottest stars are not the crucibles of nature wherein the eighty-two heavier elements are built up, where and under what conditions were they formed? A highly speculative answer is to be formed in an intensely interesting piece of theoretical research carried out during the early years of this war by Chandrasekhar and Heinrich. They have been inquiring under what conditions of nature the basic units of matter—electrons, protons, neutrons, positrons—could be expected to come together to form, in their various proportions, the atoms of all the isotopes of the elements familiar to the chemist. As these elements compose all stellar bodies as well as all things terrestrial, their synthesis is a cosmic problem. They find that such tremendous extremes of high temperature and high density would be required that it is necessary to suppose that all the matter of the known universe was once confined to a volume of radius only about twenty times that of the solar system. Such a sphere drawn around our sun as centre does not now contain a single other star. Yet into such a volume there may once have been packed not only all the thousand million stars of our own galaxy, but all the millions of other galaxies. This is indeed a picture reminiscent of the "giant molecule" of Lemaître. Since stars and galaxies are not now thus packed, expansion must have taken place some time very long ago. The present rate of expansion is such that galactic distances are doubled every 1800 million years. This gives the time elapsed, since the expansion began, as several thousand million years which is in satisfactory accord with the age of the earth as determined by other physical lines of approach and regarded necessarily as a lower limit for the age of the universe.

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This theoretical approach has now reached a point where its author can write "I think the theory now deserves to be the accepted theory—my definition of an 'accepted theory' being that it is the theory which is so far right that everyone is interested in trying to discover what is wrong with it." Can we wonder that he

pauses in his work to refer to "the devastating beauty of quantum arithmetic." This entire investigation must surely rank as one of the great adventures of the human mind exemplifying Blake's stately metaphor—"Imagination goes forth in its uncurbed glory."

VII

This brief survey of a few fields of astronomical research, incomplete as it obviously is, will serve nevertheless to indicate that pure science is not dormant, much less is it dead, during the terrible years when the vile demoniacal God of War stands astride the earth. For many years the International Astronomical Union has been an influence for understanding, and for co-operation in the search for knowledge with mutual respect and trust. It is once again temporarily in abeyance, and it will once again rise to carry on it's good work. The lesson of astronomy down the centuries has been one of international interdependence and mutual indebtedness.

The problems facing mankind are very complex,—the dealings of man with man, the attitude of nation to nation. No solutions making for international good will and world peace will be achieved by men of narrow mind, myopic sight and dwarfed soul. The far vision in time and space, the winged imagination that leaps the barrier of here and now—these are the qualities of mind and spirit needed in every walk of life and needed superlatively in the leaders of every nation if in the years just ahead of us progress is to be made towards the great ideal of international unity. How can the eyes of the blind be awakened to the dazzling vision of the City of God? For some it may be by the contagious enthusiasm of a great teacher or leader, for others the illumination from poetry, for some the spark is kindled by the study of history, or of philosophy, and for yet others it is through natural philosophy and astronomy. Mankind needs the perspective of the cosmic background. "The great values," said Field Marshal Smuts, "retain their unfading glory and derive new meaning from a cosmic setting."

There is a challenge to the scientists and to the lovers of science to teach the boys and girls, the young men and women of today and tomorrow, the ideals, the aims, the methods and the integrity of the scientific approach to facts and to problems.

We do not forget the dictum of Rabelais, "Science without conscience is damnation." Wartime drives this home with bitter and tragic intensity. But we may say with great assurance that Science with conscience has an essential part to play in procuring and maintaining world conditions in which peace can endure.

All who have the ideal of world-citizenship at heart, all who have the far vision of things that have been and of things that may be, and the realistic grasp of things that are, must cooperate in the great task of bringing into the affairs of mankind upon this earth some semblance of the order, beauty and harmony of the universe of stars. Towards this end, both directly and indirectly, astronomy and astronomers can play a part; and it may prove to be a part which no one else can play for them because they, the astronomers, are the people with the fullest understanding of the cosmic background.

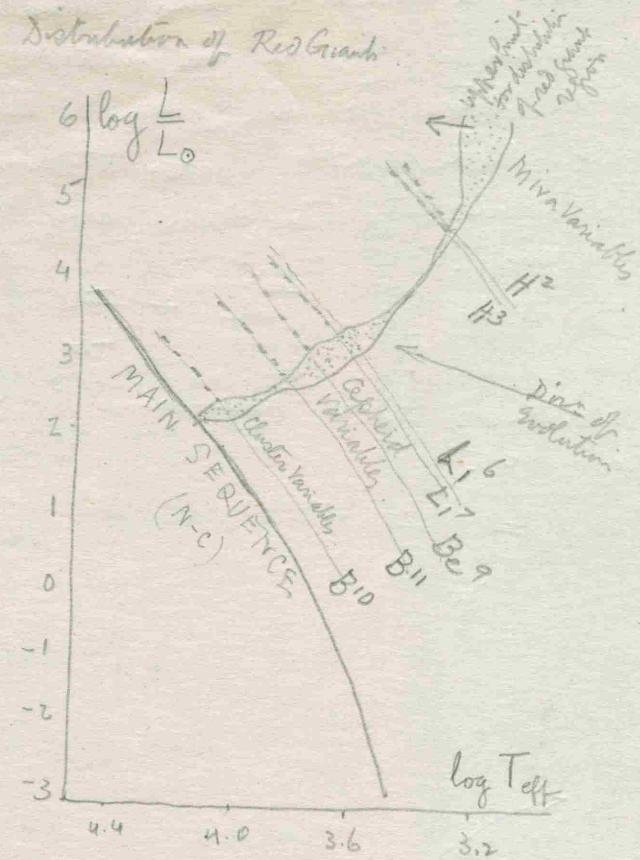
A. Vibert Douglas

Queen's University
Kingston, Ontario.
Jan. 21, 1944.

Gamow. Nature 1939. Sept 30. p575

Gamow Nature 1939. Oct 7. p621

Distribution of Red Giants



The line of pulsating stars represents the geometrical locus of points where the grav. contraction begins to play a more important part than the nuclear energy production.

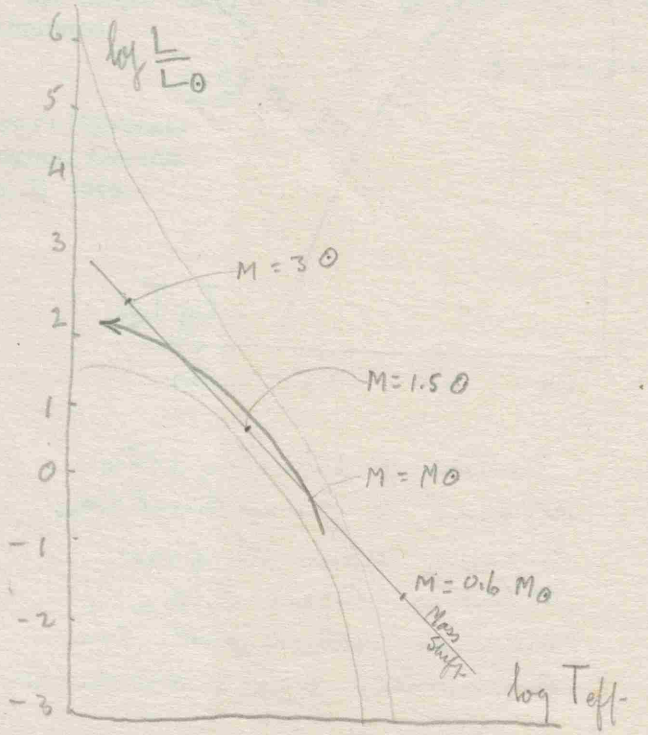
Passage through the RH stages is very rapid until Main sequence conditions are reached.

As each nuclear reaction stage is ended by exhaustion of light element concerned star undergoes rapid contraction until temp at centre is right for next nuclear reaction.

over.

above the pulsating limit almost no stars are known bec. rate of grav. contraction is so great that each star rapidly passes to main sequence condition when Carbon cycle begins.

after this T_{eff} + $\frac{L}{L_\odot}$ both increase as H is transformed by C-N cycle into He.



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p. 575, 1939.

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Phys Rev. 65 - 20. 1944

Phys. Rev.

55 791, 1939.

Sci abstracts 4503

J. Wash. Acad Sci.

32 . 353, 1942

Gamov. Nature 1939. Sept 30 p575

...te list of all pos. reactions ... protons + diff light ... lei + Q the energy prod^n ... reaction

... of Sun $T = 2 \cdot 10^7$ °C.

ρ = 80 gm/cc.

	Q
H → $^2H + e^+$ (?)	1.5
H → $^3He + h\nu$	6.9
H → $^4He + h\nu$	21.3
H → $^4He + {}^3He$	4.1
H → $2\,{}^4He$	18.6
H → $^6Li + {}^4He$	2.4
^1H → $^{11}C + h\nu$	9.2
^1H → $3\,{}^4He$	9.4
^1H → $^{12}N + h\nu$	0.4
^1H → $^{13}N + h\nu$	2.0
^1H → $^{14}N + h\nu$	8.2
^1H → $^{15}O + h\nu$	7.8
^1H → $^{12}C + {}^4He$	5.2
^1H → $^{17}F + h\nu$	0.5
^1H → $^{16}O + {}^4He$	8.8
+ ^1H → $^{23}Na + h\nu$	10.7
+ ^1H → $^{27}Al + h\nu$	8.0
+ ^1H → $^{31}P + h\nu$	7.0

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Hale 1924, 1931
Hubble 1937
Jeans 1931, 1929
Marden 1931
R.A.S. 1926 + various
Shapley, P.E. Jan 1930
Smart 1928 S.S.U.
Dingle 1924
Fowler 1936 Theor. Ap.
July 13, 1946

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Complete list of all pos. reactions betw protons + diff light nuclei + Q the energy prod

per reaction

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$^9Be + {}^1H \rightarrow {}^6Li + {}^4He$	2.4
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$^{16}O + {}^1H \rightarrow {}^{17}F + h\nu$	0.5
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$^{22}Ne + {}^1H \rightarrow {}^{23}Na + h\nu$	10.7
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These cannot be responsible for solar output - as elements have not great enough abundance + Total energy quite inadequate, ∴ only possibility is C cycle

ASTRONOMY IN A WORLD AT WAR

BY

A. VIBERT DOUGLAS

Queen's University
Kingston, Ontario

FROM THE SMITHSONIAN REPORT FOR 1944, PAGES 155–164

(PUBLICATION 3778)

SMITHSONIAN INSTITUTION
WASHINGTON
D. C.

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ASTRONOMY IN A WORLD AT WAR[1]

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I

Science has advanced during the last 4 years both because and in spite of war. Some of the sciences have made tremendous strides as a direct result of the challenge of war necessities. Physics, chemistry, metallurgy, and all the branches of medical science are in this category; some day the full story of their great achievements may be made known. Other branches of knowledge, while far from being unaffected by the war, have continued to advance largely in spite of the upheavals in the life of nations and individuals which world war inevitably brings. Astronomy is in this latter class.

Astronomy and astronomers are playing an important part in the war chiefly along the two lines which have always presented fundamentally stellar problems—direction and time. But the main advances in astronomy in these last 4 years have been made in spite of the war. It is right and fitting and indeed very encouraging that this is the case. When so much that is of intrinsic beauty and of fundamental value is being destroyed by war, and when so many worthwhile activities have to cease, it is good indeed to know that there are astronomers on this continent, and even in some parts of Europe, and in Australia, Africa, India, and probably in Japan, who are able to carry on the continuity of observations on stars and starlight, sun and moon, planets and asteroids, comets and meteors.

If the continuity of observation in many branches of astronomical work were to be completely broken, it would be an irreparable loss to science. Thus it is with satisfaction and great admiration that we read in the Reports of the Royal Observatory, Greenwich, that damage done by enemy action to one of the buildings and to the Airy transit circle has been largely made good, and observations recommenced with that instrument upon Sun, Venus, and the stars

[1] Address of the president of the Royal Astronomical Society of Canada, January 1944. Reprinted by permission from The Journal of the Royal Astronomical Society of Canada, vol. 38, No. 3, March 1944.

in the clock and azimuth lists; that parallax determinations are going on; that solar photography and observations of chromospheric eruptions in Hα are continuing; and that the two Time Service Stations have operated continuously. During this period the exhaustive work on the solar parallax was brought to completion.

In France solar, planetary, and stellar research have been carried on, and in Holland galactic problems, long-period variables, dark nebulosity, and theoretical astrophysics have been under investigation even in these tragic years. In the U. S. S. R., where at least three observatories have been destroyed and another dismantled, plans are already made for resumption of activity and for the erection of new observatories to further the study of latitude variations and solar research. From two observatories east of the farthest battle front we know that papers have been published recently on photoelectric calorimetry and on color temperatures.

Similar records of observations and measurements carried on despite air raids, despite reduction of staff, despite pressing war problems and difficulties of all kinds, could be quoted from many observatories in countries deeply involved in fighting for their very existence.

In these and in countries like our own—at war, but far removed from the main theaters of conflict—there has been a very important contribution made by astronomers in the adaptation of astronomical observations and calculations to the problems of air navigation. The Director of the Glasgow University Observatory, W. M. Smart, has produced three books on nautical astronomy since this war began, and under his instruction, R. A. F. pilots and cadets are learning the art and science of navigation. Scores of astronomers, including Canadian men well known to many of us, are doing similar work, giving all their time, skill, and energy, and often risking their lives in the air with student pilots, in order to impart this so necessary instruction in air navigation.

In the Koran, it is written: "God has given you the stars to be guides in the dark, both by land and sea." Homer tells of Ulysses on his raft that he sat at the helm and "marked the skies, nor closed in sleep his ever watchful eyes." But navigation from the back of a camel or from the bridge of a ship can be a relatively leisurely performance. Not so in a modern airplane! The navigator takes a sight on a star or planet, he reads his chronometer, and then if his calculations take him 5 minutes to perform, he and his plane are already perhaps 25 miles away from the ascertained position. Every minute that astronomers have been able to cut off the time for computation of position is of the greatest value to airmen flying over seven seas and six continents, across enemy lines, with objectives a mere dot on the map—a railway yard, a factory, an airfield.

II

Turning to the subject of time measurement, it is worthy of note that during these war years an accuracy never before dreamed of has been attained. It was in April 1938 that Essen described before the Royal Astronomical Society the researches at the National Physical Laboratory which had resulted in the new quartz clock, of which so much was hoped. This clock makes use of the properties of the crystal oscillator, one of the most reliable and perfect mechanical systems known to man. Essen describes quartz clocks briefly as "consisting of phonic motors controlled via frequency dividers by vibrating quartz crystals." In a paper presented to the Royal Astronomical Society last June, Greaves and Symms record the intercomparisons of three Greenwich free pendulum Shortt clocks, two National Physical Laboratory quartz clocks, and three quartz clocks at the Post Office Radio Branch Laboratories.

They analyze clock errors into three classes: (a) erratic variations in phase, (b) erratic variations in rate, (c) a combination of phase and rate variations, producing a cumulative effect. They show that two Shortt clocks and two quartz clocks may indicate approximately the same mean absolute second differences of relative clock error, but the distribution of errors between the three classes is different—the quartz clocks show very little error of (b) and (c) relative to Shortt clocks, and errors of class (a) do not affect the long-period performance of a clock.

The famous Shortt clocks are now known to be incapable of giving the precision demanded, but the Astronomer Royal hastened to pay them a deserved tribute:

> Twenty years ago we had several papers dealing with the performance of the Shortt clocks, then looked upon with great expectations. In this clock was achieved in a simple and beautiful manner what horologists had been striving after for years, namely, a pendulum designed solely for the purpose of beating time whilst being called upon to perform no mechanical work. But if the subsequent performance of this type of clock did not fully come up to our high expectations, the Shortt Free Pendulum has one thing to its everlasting credit—it forced the astronomers to adopt the use of Mean Sidereal Time where formerly True Sidereal Time had been adequate. During the intervening 20 years since this type of clock was installed in many observatories, new requirements have sprung up. In the past the main purpose of a time service was to provide absolute time with an accuracy sufficient for navigational and surveying requirements. But the new use of frequency standards has raised a demand for 24-hour intervals correct to the very high accuracy of a millisecond.
>
> It will be seen then that as absolute standards at Greenwich, Shortt clocks have become obsolete. Our long-range predictions are now based entirely on quartz clocks, free pendulum clocks being used only for extrapolation over an interval of 24 hours.

III

Let us turn our thoughts to cosmology and recall that it was during the first World War that Einstein's general theory of relativity appeared. Two years later, in the war year 1917, came the first suggestion of an expanding universe. This was one interpretation of de Sitter's modification of Einstein's cosmology, implying as it did red shifts of the spectrum lines of faint distant objects. Incidentally, we may turn aside to remark that while de Sitter was then working in a Holland that had been allowed to remain neutral, his spirit is living on in the occupied and battered Holland of this war, and he, though dead, yet speaketh, inspiring his successors at Leiden and Amsterdam to carry on the tradition of astrophysical research in spite of all external difficulties—thus Verweij has produced a theoretical discussion of Stark effect in stellar spectra which was published in Holland and found its way to the United States of America just before the entry of that country into this war. Perhaps I may add that Verweij in that paper dealt a hard blow at a paper by a McGill colleague and myself, though I do not accept it as a knock-out blow. Further research on this controversial subject is now in progress at the Dominion Astrophysical Observatory.[2]

De Sitter had also deduced from Einstein's theory the four conclusions which offered a hope of observational confirmation. One of these four crucial tests was whether radiant energy passing close to a body with an intense gravitational field surrounding it, would be deflected in accordance with Newton's law of gravitation or with Einstein's modification of that law. It was Prof. A. S. Eddington who realized the great importance of making this test at the first favorable opportunity, namely, at the time of the total solar eclipse which was to occur on May 29, 1919, with the Hyades as background. War or no war, all the plans and preparations were pushed ahead and thus it was that when the eventful day arrived, even though the Treaty of Versailles had not yet been signed, two British expeditions were in readiness to take the crucial photographs. I often reread the passage written by a learned mathematician and philosopher in which he described the meeting of the Royal Society when the results of these eclipse expeditions were announced, verifying as they did the theory of Einstein:

> The whole atmosphere of tense interest was exactly that of the Greek drama; we were the chorus commenting on the decree of destiny as disclosed in the development of a supreme incident. There was dramatic quality in the very staging;—the traditional ceremonial, and in the background the picture of Newton to remind us that the greatest of scientific generalisations was now, after more than two centuries, to receive its first modification. Nor was the personal interest wanting: a great adventure in thought had at length come safe to shore. [A. N. Whitehead.]

[2] Recent work at the D. A. O. points to a confirmation of the work of Foster and Douglas on the interpretation of helium profiles.

De Sitter's expanding universe suggested an outward motion of the stellar bodies within the framework of space as defined by his modification of the Einstein equation of spacetime geometry. Ten years later, Lemaître, who had fought with the Belgian army in the war years and afterward entered Louvain University, brought forward his theory of expanding space. This made the radius of curvature of space a function of time, and gave a new stimulus to the astronomers in those great observatories equipped to probe most deeply into space. In the following years, at Mount Wilson and Harvard particularly, the exploration of space was carried on with vigor, and methods were found of estimating the distances of the remote galaxies. A special lens was designed to obtain their spectra at Mount Wilson, and thanks to the broad, strong H and K lines of ionized calcium, red shifts could be measured to distances estimated as 250,000,000 light-years. The correlation between distance and red shift has provided a remarkable confirmation of the theory of the expanding universe. Recessional velocities up to one-seventh the velocity of light have now been observed. In the years between the wars a few voices were heard to question the interpretation of the red shift as a Doppler displacement, but since no alternative explanation suggested itself without postulating some entirely new law of Nature, the expanding universe remained as a working hypothesis in the background of most astronomers' minds.

One of the interesting things that these recent war years have brought is the reopening of this question by E. P. Hubble. Is the universe expanding? Is the red shift actually indicative of motion? Or is the framework of the universe static? And if static, what is the explanation of the displacement of all spectrum lines to the red for distant galaxies? Hubble's analysis of all available data based on the assumption that the universe is expanding, necessitates the calculation of a dimming factor due to recession. When correction is made for this in the estimation of distances, he claims that a map results which is not of homogeneous density, which implies an increasing rate of expansion with distance, and therefore an "age" of the universe totally inadequate. On the other hand when he assumes a static framework for the universe, the analysis of all the data gives a map that shows a linear relation between red shift and distance, and a homogeneity of density. This map has more to commend it than has the former map, and hence the assumption of a static framework appears to be favored. But, as various astronomers have pointed out, the weakness of this result lies in the large probable errors of the quantities involved, so that even an apparent divergence of 30 percent from uniformity of density is not evidence weighty or certain enough to overthrow the Lemaître theory of an expanding universe.

IV

Important advances have been made recently by Gamow and Bethe in our understanding of the sources of energy within stars which permit them to radiate energy as they do. Bethe has given an exposition of a cyclical sequence of atomic changes and interactions whose net result leaves a star with fewer hydrogen atoms, but with more helium and the liberation of excess nuclear energy in the form of gamma rays. This is now generally referred to as the carbon cycle and it is too beautiful not to be recorded here, for though published a few months before the war, it has been during the war years that it has become a part of astronomical thinking. Of the six stages, four result from collisions with hydrogen atoms in the deep, hot interiors of main sequence stars, and two are spontaneous disintegrations of unstable nuclei.

1. $C^{12} + H^{1} = N^{13} + \gamma$
2. $N^{13} \rightarrow C^{13} +$ positron
3. $C^{13} + H^{1} = N^{14} + \gamma$
4. $N^{14} + H^{1} = O^{15} + \gamma$
5. $O^{15} \rightarrow N^{15} +$ positron
6. $N^{15} + H^{1} = C^{12} + He^{4}$

The two positrons rapidly interact with electrons to give rise to gamma radiation. Thus is produced the penetrating radiation, most of which in the course of its progress toward the boundary of the star becomes transformed into the heat, light, and ultraviolet radiation that pour out from the photosphere. The central temperatures of the cool giant stars are insufficient to maintain this active cycle, but theory can explain their radiant energy in terms of atomic collisions and transmutations which are, however, noncyclical. Hydrogen, deuterium, lithium, beryllium, boron are slowly transformed into helium.

If the central regions of the hottest stars are not the crucibles of nature wherein the elements are built up, where and under what conditions were they formed? A highly speculative answer is to be found in an intensely interesting piece of theoretical research carried out during the early years of this war by Chandrasekhar and Heinrich. They have been inquiring under what conditions of nature the basic units of matter—electrons, protons, neutrons, positrons—could be expected to come together to form, in their various proportions, the atoms of all the isotopes of the elements familiar to the chemist. As

these elements compose all stellar bodies as well as all things terrestrial, their synthesis is a cosmic problem. They find that such tremendous extremes of high temperature and high density would be required that it is necessary to suppose that all the matter of the known universe was once confined to a volume of radius only about twenty times that of the solar system. Such a sphere drawn around our sun as center does not now contain a single other star. Yet into such a volume there may once have been packed not only all the thousand million stars of our own galaxy, but all the millions of other galaxies. This is indeed a picture reminiscent of the "giant molecule" of Lemaître. Since stars and galaxies are not now thus packed, expansion must have taken place some time very long ago. The present rate of expansion is such that galactic distances are doubled every 1,800 million years. This gives the time elapsed, since the expansion began, as several thousand million years which is in satisfactory accord with the age of the earth as determined by other physical lines of approach and regarded necessarily as a lower limit for the age of the universe.

The last chapter on these cosmological problems is not yet written—indeed there may well be many chapters yet to come and still no last chapter in sight. It is the glory of the quest that as men seek the unexplored horizon the margin fades forever and forever as they move.

V

An investigation of very recent date has led to positive conclusions about planetlike bodies associated with stars other than our sun. There is strong evidence for this in the case of 61 Cygni and 70 Ophiuchi. This may be the beginning of a new search and a new certainty in a field of astronomy hitherto theoretical and speculative. Already several astronomers on two continents are studying the implications.

Another astrophysical problem that has been worked upon with considerable success during these war years, is the old backlog problem since 1869 of the solar corona. At Uppsala, Edlén has been examining the X-ray and ultraviolet spectra of some very highly ionized atoms, and a year ago his 1942 paper was received in England and also in the United States of America. He uses his laboratory data as basis for calculation of forbidden lines and altogether he identifies 17 coronal lines with lines of Fe X, XI, XIII, XIV, XV, Ni XII, XIII, XV, XVI, Ca XII, XIII, A X; and two other lines less certainly with Ca XV and A XIV. The ionization potentials required to produce such atoms are very high, actually 233 volts for Fe X, 655 volts for Ca XIII, and at first this seemed to offer an insuperable obstacle to acceptance of Edlén's proposals. The age-old question of Nicodemus arose—how can these things be? These atoms are many thousand miles from the photosphere of the sun; and to produce such ionization, temperatures of 2,000,000 degrees are necessary. Speculation and calculation have followed. A few months ago an explanation was given in a letter to Nature by V. Vand of London. Even higher temperatures he shows to be possible in the low-density regions of the corona as a result of collisions of high-velocity atoms falling toward the sun from interplanetary space. With the greater density of the inner corona and consequent increase in radiation losses, he believes conditions may be favorable to just those transitions postulated by Edlén.

VI

The numbers 136, 137, 256 will awaken in the minds of many of you memories of a kindled interest, of perplexity, doubt, expectation, and perhaps of moments of great thrill, as you think back over the last 15 years. One name alone stands central among these memories—that of Sir A. S. Eddington. This has been his playground pre-eminently. Some of us have stood fascinated at the edge of the field watching this illusive game played patiently, skillfully, brilliantly by one man, a master juggler with the elements of the theory of groups, with quantum mechanics, and with the basic units of measurement, producing, as from the proverbial hat, physical constants both atomic and astronomical. Some there have been who paused to watch briefly, to smile or even ridicule the Aristotelian tour de force. But steadily and doggedly the theory has been pushed forward, several papers having appeared in the last 3 years until now the evidence is overwhelmingly great that, with no observational data other than three basic constants, namely, the velocity of light and the Rydberg and Faraday constants for hydrogen, it is possible to calculate theoretically the following 13 physical constants: charge e; Planck's constant; masses of electron, proton, hydrogen atom; gravitation constant; fine structure constant; nuclear range-constant; nuclear energy-constant; mass of universe; number of particles in universe; Einstein radius of space; nebular speed. This is a striking achievement.

Let us look briefly at just two of these constants. The recessional velocity of the spiral nebulae is calculated to be 572.36 km. per second per megaparsec. The observational value of Hubble and Humason is 560. When the great 200-inch reflector comes into action, we shall expect to see the observational value come closer to Eddington's determination.

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VII

This brief survey of a few fields of astronomical research, incomplete as it obviously is, will serve nevertheless to indicate that pure science is not dormant, much less is it dead, during the terrible years when the vile demoniacal God of War stands astride the earth. For many years the International Astronomical Union has been an influence for understanding, and for cooperation in the search for knowledge with mutual respect and trust. It is temporarily in abeyance, but it will once again rise to carry on its good work. The lesson of astronomy down the centuries has been one of international interdependence and mutual indebtedness.

The problems facing mankind are very complex—the dealings of man with man, the attitude of nation to nation. No solutions making for international good will and world peace will be achieved by men of narrow mind, myopic sight, and dwarfed soul. The far vision in time and space, the winged imagination that leaps the barrier of here and now—these are the qualities of mind and spirit needed in every walk of life and needed superlatively in the leaders of every nation if in the years just ahead of us progress is to be made toward the great ideal of international unity. How can the eyes of the blind be awakened to the dazzling vision of the City of God? For some it may be by the contagious enthusiasm of a great teacher or leader, for others the illumination from poetry, for some the spark is kindled by the study of history, or of philosophy, and for yet others it is through natural philosophy and astronomy. Mankind needs the perspective of the cosmic background. "The great values," said Field Marshal Smuts, "retain their unfading glory and derive new meaning from a cosmic setting."

There is a challenge to the scientists and to the lovers of science to teach the boys and girls, the young men and women of today and tomorrow, the ideals, the aims, the methods, and the integrity of the scientific approach to facts and to problems.

We do not forget the dictum of Rabelais, "Science without conscience is damnation." Wartime drives this home with bitter and tragic intensity. But we may say with great assurance that science with conscience has an essential part to play in procuring and maintaining world conditions in which peace can endure.

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(*Reprinted from* NATURE, *June* 9, 1928.)

ASTROPHYSICAL ESTIMATES OF IONISATION POTENTIALS OF IRON, YTTRIUM, AND LANTHANUM

THE work of Saha, Fowler, and Milne has shown how the intensities of ionised lines in stellar spectra are dependent upon temperature, pressure, ionisation, and excitation potentials. By studying the changes in intensity of a line from stars of one spectral class to another, astrophysical estimates have been made of the ionisation potentials of certain of the elements by several investigators.

In the case of a *Cepheid variable*, we have a star the luminosity of which changes slowly from maximum to minimum, then rises steeply to maximum again, with a regularity which is remarkable. During the same period the radial velocity goes through a cycle of changes as though the star were in a state of pulsation, expanding and then contracting, with consequent cyclic changes in the pressure and temperature of its outer portions giving rise to periodic variations in spectral classification.

Dr. F. C. Henroteau recently enlisted my interest in the variations in intensity of certain ionised lines, and in the course of an investigation of more than seventy spectrograms of η Aquilæ taken at the Dominion Observatory during the last few years, the behaviour of some twenty lines due to ionised atoms of scandium, titanium, iron, strontium, yttrium, barium, lanthanum has been studied. Microphotometer graphs of each spectrogram were made. An arc line insensitive to the periodic changes was selected closely adjacent to each of the spark lines under consideration and the ratio of the enhanced line to the arc line measured in each case. Plotting these ratios against phase (in η Aquilæ the period is 7·176382 days) the resulting curves exhibit general resemblance to one another but certain differences in position of maximum and spread of high values which must be attributed mainly to differences in ionisation potential. Taking the following known ionisation potentials :

At. No.	Element.	Ionisation Potential.
21	Sc	6·7 (Russell and Meggers)
22	Ti	6·5 (Kiess and Kiess)
38	Sr	5·67 (A. Fowler)
56	Ba	5·19 (A. Fowler)

as the basis, *the ionisation potentials of iron, yttrium, and lanthanum are estimated to be as follows :*

At. No.	Element.	Estimated I.P.
26	Fe	6·6 (5·5)
~~41~~ 39	Y	6·6
57	La	4·9

In the case of iron, the alternative estimate (5·5 volts) is got by comparison with the graphs for strontium and barium, while the estimate 6·6 volts is the value relative to scandium and titanium. Spectroscopic values have been given as 5·9 and 8·15 by Sommerfeld, Gieseler, and Grotrian, while astrophysical estimates by Menzel are 7·5 and ~~13·0~~.

As regards yttrium, a spectroscopic determination has just been announced at the Washington meeting of the American Physical Society (April 20), by Meggers and Russell, agreeing with the above, 6·6 volts. This is of interest because the astrophysical estimates are certainly subject to large probable error.

For lanthanum I am unaware of any previous determination, and in confirmation of this and the other estimates, further study of the behaviour of sensitive lines in the spectra of Cepheid variables will be carried out. I am indebted to the Director of the Dominion Observatory for permission to utilise data taken from spectrograms belonging to that institution.

A. Vibert Douglas.

McGill University,
April 25.

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ASTROPHYSICAL ESTIMATE OF IONISATION POTENTIAL OF VANADIUM

In a previous letter (NATURE, June 9, 1928) I outlined the method by which estimates of ionisation potentials might be derived from the spectra of Cepheid variables. Many of the lines emitted by ionised atoms are intensified at or near maximum luminosity phase and diminish in intensity as the star passes through the phase of minimum light. Many arc lines, on the other hand, show the reverse tendency. By comparing the behaviour of certain ionised lines with spark lines due to titanium, scandium, strontium, and barium, the ionisation potentials of which are known, it has been possible to estimate this constant for iron, yttrium, and lanthanum (loc. cit.), and quite recently for vanadium. From the periodic changes in intensity of the ionised line λ4205·07 I have obtained for the *ionisation potential of vanadium* 6·74 *volts*, the final figure being extremely uncertain.

In a recent letter from Dr. W. F. Meggers, Bureau of Standards, Washington, I am reminded that Prof. H. N. Russell (*Ap. J.*, 66; 1927) has obtained the principal ionisation potential of vanadium from spectral series relations to be 6·76 volts. I am unaware of any laboratory determination of this quantity, but the close agreement between the spectroscopic and the present astrophysical determination is very satisfactory.

As before, I am under obligations to the Director of the Dominion Observatory, Ottawa, for the loan of the spectrograms from which my microphotometer graphs have been made.

A. VIBERT DOUGLAS.

McGill University,
Montreal, Feb. 28.

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ASTRONOMY, PHYSICS, AND PHILOSOPHY

By

A. VIBERT DOUGLAS

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ASTRONOMY, PHYSICS, AND PHILOSOPHY

By A. Vibert Douglas

(THE ADDRESS OF THE RETIRING PRESIDENT OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA)

I

IN the search for knowledge, whether it be knowledge of the physical world close around us or of the vast universe external to the earth or whether it be knowledge in the realm of philosophy and human conduct, the starting point is faith and the first step is frequently taken by the guidance of intuition. Then reason carries on, working inductively upon the facts of observation and experiment and deductively from the resulting generalizations, hypotheses and theories to point out crucial tests and observations. In the light of the results of these crucial tests, the generalizations must then be reconsidered. Thus the scientific method gets underway and whither it leads the honest seeker after truth must follow. "Trust in reason," wrote Dean Inge voicing in this age the thinking of Clement of Alexandria in the sixth century, "in reason which rests ultimately upon faith in the Divine Logos, the self revealing soul of the Universe." "In the age of reason," says Sir Arthur Eddington, "faith yet remains supreme; for reason is one of the articles of faith."

This basic and fundamental position of faith in the realm of ethics and the moral law is said to be the main thought behind Dostoevski's great novel, *Crime and Punishment*. In a recent article by E. M. Dodd on this subject, it is stated that recognition of Moral

Law "is not an act of Reason in the sense of intellection . . . Reason cannot exalt Altruism into an obligation nor establish the idea of the sanctity of human life; these perceptions are the reward of Faith, and it is in virtue of them alone that Reason is relevant to human life at all." Whether or not we are convinced that this is true of all men, we may probably agree with the late Poet Laureate when he writes "Verily by Beauty it is that we come at Wisdom yet not by Reason at Beauty."

In the realm of science we find the basic rôle of faith enunciated thus by A. N. Whitehead: "Faith in reason is trust that the ultimate natures of things lie together in harmony which defies mere arbitrariness." It is this faith in the order of Nature that has sustained men of science in their search for truth in spite of all difficulties, false clues, shattered theories and apparent failures; it has led them to defy discouragement and to erect through the centuries the stately edifice of science which we know today, an edifice that is growing before our eyes and will continue to grow as long as thinking man inhabits the earth.

Man's reliance upon an intuitive leading is no less certain here than in the realm of philosophy. Three of the greatest mathematicians of our time have borne testimony to this fact. Describing his attempt to derive from "world-geometry" not only gravitational phenomena, as in the pioneer work of Einstein, but also the full range of electromagnetic phenomena, Weyl says that in order "to bring about the transition from affine to metrical geometry we must once more draw from the fountain of intuition." Similarly, Lemaître, referring to one particular line of reasoning at the outset to his theory of an expanding universe, writes that "this method provides a very intuitional way of considering the equations of the universe." Eddington has written as follows: "In science we sometimes have convictions as to the right solution of a problem which we cherish but cannot justify; we are influenced by some innate sense of the fitness of things."

We should not forget however that though intuition may suggest a starting point it must never be thought of as providing a resting place. It is reason that must take this wisp of intuitive thought and examine it, test it, stretch it, weave it, harness it. Thus in their

fundamental approach to the furtherance of knowledge we see that philosophy, physics and astronomy have much in common. It is equally true that there have been strong mutual influences exerted by each on the others as knowledge grew in these fields.

II

Within the interlocking fields of mathematics, physics and astronomy, the influences have been continuous and sometimes spectacular. Both physics and astronomy depend upon mathematics as a tool. The investigations into conic sections by Appolonius of Perga and other early geometers were ready to hand when Kepler, many centuries later, sought out his empirical laws of planetary motion. When Newton subsequently established their theoretical validity in terms of the inverse square law of gravitation, and when he investigated the trajectories of projectiles, it was this geometry that he found to be applicable. When he encountered certain fundamental problems in mechanics and stellar dynamics and discovered his mathematical tools to be inadequate, Newton invented fluxions. Other problems remained unsolved until Sir William Rowan Hamilton invented quaternions.

The investigations into non-Euclidean geometry by Gauss, Lobatchevsky and Riemann and the developments of tensor calculus by Ricci, Levi-Civita and Christoffel had produced mathematical tools which it was the genius of Einstein to recognize as best suited in the representation of physical phenomena. Einstein's pioneer work led to the cosmological researches of de Sitter, Weyl, Eddington, Lemaître, and subsequently of Milne, Schroedinger and Saxby.

When atomic physics and spectroscopy were faced with problems and difficulties which appeared insoluble, de Broglie initiated a new era with wave mechanics. New mathematical forms had to be invented, hence Dirac's wave-tensor calculus. Physics found new applications for determinants and theory of groups. So, too, in astronomy it was when the investigation of stellar structure was seen to involve Emden's equation that R. H. Fowler turned his attention to this problem and obtained a complete classification of all solutions of this important second-order differential equation, a permanent and beautiful contribution to pure mathematics. We need not labour this point: obviously Supply and Demand or Demand and Supply are operative principles in this realm of intellectual effort, and whether it be competitive or cooperative at the outset the result is always ultimately and cumulatively beneficial to all future investigators in these fields.

III

The close association between physics and astronomy can best be illustrated by means of a parable.—Two young investigators filled with the curiosity, imagination and faith of the scientists, came to Dame Nature and said: We wish to give our lives to scientific research, what shall we do? To one Dame Nature replied, Take thou the atom. To the other she said, Take thou the star. Perhaps you think, as they did, that their paths would never cross, the one in his laboratory delving into the profundities of things so small that no microscope will reveal them, the other in his observatory photographing a distant galaxy of many thousand million stars. You can imagine that each might become discontented with his lot, and, with that strange perversity of human nature, the one may return to Dame Nature and say: You told me to study atoms, but I should like to study stars! And the other may come back and say: You told me to study stars, but I want to study atoms! And Dame Nature will smile quietly as she replies: Yes, I told you to study the atom; return to your laboratory, bend all your energy to the task and some day you will find that the walls of your laboratory are expanding and expanding until they include—the stars. To the other she will make answer: Yes, it is true that I told you to study stars; return to your telescope, your spectrograph and your measuring instruments and lo! very soon you will discover that you are really studying atoms. This is not merely a parable, it is the actual truth.

In the light from the limb of the sun observed just before and after totality at the eclipse of 1868, an intense yellow ray was noted to which the astronomers could give no identification. The unknown atom was given the name helium because of its solar origin. Here was a challenge to the physicists and chemists, but not until 1895 did Ramsay, the chemist, find this element in the earth's atmosphere; not until some ten years later did Rutherford, the physicist, find by spectroscopy that the alpha particle, one product of radio active disintegration, is the nucleus of a helium atom; and not until the years of the first Great War was helium found in natural gas from certain wells.

Physics has been hampered in its efforts to determine the properties of matter by the existing limitations of terrestrial laboratories. How matter behaves at extremely low temperatures was not known until the development of cryogenic laboratories first at Leyden, and afterwards at Toronto and elsewhere. In high temperature investigations, the limit was until relatively recently the crater of the arc in an electric furnace—a region whose temperature just overlapped that at the radiating surface of the cooler stars. This is where astrophysics took up the investigation and observed the behaviour of matter at successively higher and higher temperature.

Today in terrestrial laboratories it is possible to obtain temperatures up to 6,400°C. with a specially controlled tungsten arc and experiments with exploding wires under high potential indicate peak temperatures of between 19,000°C. and 20,000°C. In the photospheres of stars of classes G to B the astroyphysicist has sources of continuous radiation from matter at these temperatures. The central stars of some planetary nebulae have surface temperatures which may be as high as 100,000°C. This estimate is based upon the fact that a lesser temperature would not permit of radiations which can produce in the surrounding nebulous gases high ionization such as thrice ionized oxygen. Beyond this we may not go by direct observation but astronomers have calculated the temperatures in the deep interiors of stars as exceeding 10^7 degrees. This has been done by mathematical investigation of the equilibrium conditions from photosphere to centre checking results by the observed output of energy. If the central temperature of a star be postulated too high, the liberation of energy would be so great as to blow off the surface layers by the violence of radiation pressure. On the other hand too low a central temperature would result in a general collapse of the gases forming the outer layers under gravitational forces unbalanced by sufficient gas and radiation pressure. Sir Arthur Eddington was a pioneer in this work.

upon philosophy. Yet it is still very true that the inward drama of the soul and the dramas of the mind and of mankind are often profoundly influenced by the drama of the physical world where the actors are radiations, electrons, atoms and stars.

In the ancient world with its geocentric cosmology it was natural for very great importance to be attached to man. For him the sun and moon were created to give light upon the earth, for him the stars marched nightly across the sky, for him the seasons brought seed-time and harvest, for his sins the earth was visited by drought or quake or pestilence. The importance of man in the scheme of creation was sung by the Psalmist—What is man that Thou are mindful of him . . . Thou hast made him a little lower than the angels and hast crowned him with glory and honour . . . Thou hast put all things under his feet." Shakespeare had caught this spirit when he wrote his famous "What a piece of work is man! how noble in reason! how infinite in faculty! . . . in action how like an angel! in apprehension how like a god!"

When the Copernican cosmology replaced the Ptolemaic, the importance of man became no longer an obvious deduction from a survey of the physical world, and an assertion of his intrinsic importance had to be supported by arguments based solely on his intellectual or spiritual worth. This has been the case ever since. To some types of minds in whatever age the spiritual reasons always outweighed the purely physical, but there are other people to whom it comes as a great shock that man appears to be but an accidental development in very recent ages upon this little old earth, a minor planet, revolving about one quite ordinary dwarf star whose position is somewhere far out from the centre of one of the many millions of galaxies of stars. To minds of this type the Copernican cosmology represents a major upheaval of what had become traditional thought. Astronomy thereafter pictured man as a mere speck in the immensity of space, and a late-comer in time. Then geology joined forces with astronomy to measure out time by era upon era, so that the average span of a human life is to the estimated age of the earth as one minute of time to three score years and ten. Biology added to the mental upheaval by appearing to present a rigidly mechanistic view of life —the great conceptions of evolution, of natural selection, the discoveries of physiological and psychological sciences being swallowed, unmasticated and often misunderstood, by a hungry or a gullible multitude. Bishop Gore thought the effect of all these ideas upon the religious imagination, could hardly be exaggerated:- "They seemed as represented in popular literature almost to obliterate God, behind a self developing universe, and to reduce the position of man to insignificance." In our own day the great challenge is once more coming from astronomy, according to Bishop Headlam. The great popularity of various non-technical books dealing with the recent discoveries in astronomy, astrophysics and atomic physics has brought thousands of people face to face with some of these facts for the first time; and they are mentally and spiritually staggered by the immensities of time and space, and by what seems to them the grandeur or the grimness of inexorable law. It is worth noting that it is the readers rather than the authors who react in this manner. The average reader will frequently draw extreme conclusions and be swayed into adopting an essentially illogical attitude of mind very far from the position which the author himself holds and intended to convey.

It is strange that men are so easily appalled by large numbers— but it is none the less certain that this is a very usual reaction. One blade of grass is intrinsically quite as wonderful as a thousand blades of grass, and ten thousand million stars are no more wonderful than is one star, yet man is overawed by mere number. We see this in Shelley, for whom "the plurality of worlds—the infinite immensity of the universe is a most awful subject of contemplation. He who rightly feels its mystery and grandeur is in no danger . . . of deifying the principle of the universe." Yet the men who actually count the stars, measure their distance, and time their revolutions are very rarely the men who deny God, the Creator of the universe. Contemplating the evidence for cause and effect—the reign of law— in the physical universe, Shelley exclaims, "Necessity! thou mother of the world!" and in his footnote he draws this conclusion "The doctrine of Necessity tends . . . utterly to destroy religion."

A few years before Shelley had written these negations in footnotes to *Queen Mab,* the very same astronomical discoveries and the great achievements of Newton were influencing the thoughts of

Immanuel Kant; but very different were his reactions. The grandeur of a planetary world, the Milky Way, the nebulae, super-systems of stars—"the infinite field of Creation—the work of God—the great Builder of the universe—We see the first members of a progressive relationship of worlds and systems—an abyss of real immensity in presence of which all the capability of human conception sinks exhausted, although it is supported by the science of number. The wisdom, the goodness, the power which have been revealed are infinite." Kant's affirmation is well known that two things moved him to reverence—the starry heavens without and the moral law within.

In Pascal we see a philosopher overwhelmed equally by the vastness of the visible world, which is itself but "an imperceptible speck in the ample bosom of nature" and by the abyss within the smallest conceivable particle of matter. Between these two extremes, he stands silent. For him there is no easy acceptance of a God revealed by Nature—a reign of Law, yes; the sublime triumphs of mathematical expression of natural law in the outer universe were in progress. Copernicus, Bruno, Kepler, Galileo, Bacon, Descartes, these were the influences so potent upon thought in the 17th Century, and on Pascal and Spinoza these influences made deep impression. But while the former turns from the outer world of nature to seek God in the spirit of man, the latter finds Him "the immanent cause of all things. . . . From the infinite nature of God, all things follow by necessity."

Given a completely random assemblage of all the energy of the stellar system, what is the probability of the present state of organization having come about by pure chance? This is the question asked and answered by Sir James Jeans whose calculation showed that the probability was so incomprehensibly small as to indicate rather impressively the logical need for a Creator, a Great Architect of the universe. Bruno arrived at a similar conclusion without climbing up a ladder of mathematical reasoning—"For things have not come about by mere accident, but through the determining mind." Whitehead likewise reaches this conclusion by no devious path—"The order of the world is no accident—the religious insight is the grasp of this truth."

There is a class of public speakers and writers who misunderstand and misuse modern scientific thought in an effort to obtain oratorical effect or to bring into sharp relief the contrast between the physical and the moral order. A stock phrase is that the physical universe is "a soulless repetitive mechanism." The picture conjured up before the mind is of stars and planets endlessly circling about their appointed orbits for ever and ever and a day—a picture of futility and changelessness; and against this mechanistic principle of nature the spirit of man is urged to fight. This conception is contrary to the true astronomical and physical picture, and much loose thinking is woven about it.

No one can ponder upon the solar system, upon the great multiple star systems, or upon the beautiful photographs of the spiral galaxies, and argue that this is a static universe. It is obviously a dynamic universe; but it is not the arena of haphazard change nor of mere repetition—it is a dynamic universe of directed change. All the change that goes on in the physical universe is towards unavailability of energy; "physically wasting but spiritually ascending," to quote the comment of Professor Whitehead who in those five words reveals himself as both physicist and philosopher. Thinking not only of cosmological changes but also of the geological and biological changes which the centuries and eras reveal, Herbert Spencer framed his evolution-formula, postulating that development in all things proceeds from a state of "indefinite unstable homogeneity" towards a "definite stable heterogeneity." It is important to note that in this famous metaphysical speculation there is no suggestion of mere repetition.

V

The dynamic phrase, The Prime Mover, is one of Aristotle's great contributions to metaphysical thought. The Greek philosophers were steeped in the astronomical knowledge of their day, and cosmological speculation flourished in their midst. Asked what was the chief object of being born into this world, Anaxagoras replied—To investigate the sun, moon and heavens. And Plato impressed upon his students that theirs was the high task of finding "what are the uniform and ordered movements by assuming which the motions of the planets can be explained." That the sun, moon, planets and stars moved, and moved in obedience to some law, was an observation of tremendous significance to the Greek philosophers. When Aristotle sought to complete his Metaphysics, he was driven inevitably and inexorably by the force of dispassionate logic to postulate the great Prime Mover. The significance of this can scarcely be overemphasized. It has influenced much philosophic thought down to the present day. It is one of the strong influences playing upon the mind of Whitehead when he undertakes the difficult task of restating a metaphysics in terms of modern language in the light of modern knowledge. With the passing of the very limited and artificial cosmology of the Greeks, the metaphysical need of God as the Prime Mover has disappeared. Motion, in the thought of the natural philosopher of the 20th Century is simply one of the many forms of energy. But an analogous metaphysical need does arise, and Whitehead is led to the conclusion that "the general character of things requires that there be such an entity. . . . God as the Principle of Concretion."

The sport of sports to the master cosmological thinkers during the past twenty years, has been to devise mathematical equations representing various geometries of space and time; equations from which would arise, or within which are embedded, so to speak, as identities the mathematical representations of the laws of nature as the astronomer and as the physicist sees them. This means that the so called laws of nature are not edicts imposed from without—the law of gravitation for example, is not what it is because the Prime Mover propels the planets around certain orbits with certain velocities. The laws of nature are what they are because the universe including the mind of man is what it is—a sentence that is inspired by Whitehead's remark that "the electron does what it does because it is what it is," which saying can be glibly made, but carries a meaning not entirely on the surface.

Now each one of these proposed cosmological equations may represent a theoretically possible universe and there may well be an infinity of such possibilities, but no one of the entries (whether of Einstein, or de Sitter, or Lemaître or other) has won the blue ribbon, because no one of their equations truly and completely represents the actual universe. Furthermore even if such an equation be formulated, this fact still remains obvious that this equation is only one of the many representing theoretically possible universes. "We conceive actuality as in essential relation to unfathomable possibility." (Whitehead)

The prime command and its result, are set forth in the Book of Genesis with stately simplicity—"And God said, Let there be light, and there *was* light"—not any kind of light, with any of the many different properties one might imagine that light could conceivably display; but the particular kind of light that plays so basic a part in our physical experience, the light whose properties are so beautifully set forth in the Maxwellian equations and quantum laws. "Every actual occasion is a limitation imposed on possibility," to quote again from the author of the phrase, the Principle of Concretion, "God is the ultimate limitation—God is not concrete, but he is the ground for concrete actuality."

Two of the baffling mysteries which challenge the mind of the philosopher are space and time. Into what category is he to put them and how define them? Newton, Leibnitz and Kant strove to clarify these terms. Newton took them for granted as things-in-themselves, —eternal, infinite, self-subsisting—a point of view that drew fire from Kant. Leibnitz classified them as ordinary concepts, to which Kant raised the objection that ordinary concepts have instances, whereas there is but one space and one time. Kant regarded space and time as the forms of perception, external and internal, respectively; in no sense things-in-themselves, yet not illusions; transcendentally ideal, but empirically real. While this critical sifting of words and ideas went on and on, the absolute Euclidean space, and "absolute, true and mathematical time" accepted explicitly by Newton, provided the frame-work within which the Newtonian celestial mechanics functioned with spectacular success for nearly two hundred years. Then the triumphant chorus of astronomical approval of absolute space and time began to falter. The motion of the perihelion of Mercury's orbit refused to conform to Newtonian calculations. Physics likewise provided food for thought—the earth's motion relative to the ether could not be detected, and the apparent mass of an electron was found to be a function of its velocity.

Einstein's Theory of Relativity swept absolute space and absolute time from the astronomical, the physical and the philosophical horizons. Three out of four crucial tests of this theory were astronomical; and it is the astronomers, naturally, who are providing the observational data that is hurling out the frontiers of explored space to almost inconceivable distances. The velocity of light being finite, the astronomer is looking backward in time as he looks outward in space. How far he is justified in interpreting what he sees in the stellar universe in terms of physical laws established in a "Here-Now" environment is a question upon which it is not wise to be dogmatic. P. W. Bridgman has warned that such a procedure applied at the limits of the astronomical time scale is a "hair raising extrapolation"! Into the thoughts of many cosmologists has come the idea that what appear to us as laws of nature are relationships between phenomena which are the result of the sum total of physical conditions as they now are, and of the selection from this sum total which is made by the mind of the natural philosopher, a selection largely dictated by the mind's own limitations. Eddington has stressed this latter part, the subjectivity of the laws, while repudiating the former part on epistemological grounds. He has said, "The constants of nature (apart from our arbitrary units) are numbers introduced by our subjective outlook, whose values can be calculated *a priori* and stand for all time."

Philosophy attempts to survey all knowledge and fit the significant principles of all departments of knowledge into a coherent whole. When Heisenberg's Principle of Uncertainty was enunciated in 1927 it very soon became grist for the philosophers' mill. Some refused to accept this indeterminism as intrinsic in the universe, attributing the uncertainty in position and momentum of a particle to man's inability to observe and measure with sufficient accuracy or to an inadequate formulation of the concepts of physics; quite failing to grasp the significance of the fact that the products of these two uncertainties is a constant. The law of causality has dropped completely out of physical science in the sense that the present system of fundamental laws can deal with probabilities but cannot predict the future of the universe. This is a fact not yet fully assimilated by philosophy. Some amateur philosophers have taken the fact of indeterminism as an argument for freedom of will in the individual—a misuse of ideas relevant to the realm of physical science which is wholly to be deprecated.

Twenty-five years ago natural philosophers and metaphysicians faced what appeared to be a deep gulf fixed between atomicity and the entire realm of macroscopic phenomena. No mathematical bridge led from quantum theory to the theory of relativity. From 1924 onward Eddington worked relentlessly to produce "a harmonization rather than a unification," of these two. The result is a theory which relates all the fundamental physical constants both atomic and cosmic. In 1936 he wrote, "Unless the structure of the nucleus has a surprise in store for us, the conclusion seems plain—there is nothing in the whole system of laws of physics that cannot be deduced unambiguously from epistemological considerations." The link is made by identifying a function of the number of independent wave-systems existing in the universe with the ratio of electrical to gravitational force between a proton and an electron. This work stands as a monument to a very great thinker. He has written (1932): "A slight reddening of the light of distant galaxies, an adventure of the mathematical imagination in spherical space, reflections on the underlying principles implied in all measurements, nature's curious choice of certain numbers such as 137 in her scheme—these and many other scraps have come together and formed a vision." And with a humorous touch he adds—"a most rare vision . . . Bottom's dream."

This work has drawn fire from Dingle, Born and others because they regard with distrust such pure Aristotelianism. Born has recently written "If they (Eddington's results) should turn out to be right I shall rejoice. But I shall not attribute this (possible) success to Eddington's philosophy, as a doctrine which could be followed by others, but to his personal genius and intuition." This, to my ears, has the sound of evasion. The Astronomer Royal has ventured the opinion that "it may well be that generations yet to come will regard Eddington's recent work as one of the most important and significant advances in science." Unfortunately few scientists and fewer philosophers have the mathematical competence to understand it fully.

Other avenues of attack have been explored in 1943-44 by Saxby, by Einstein and Bargmann, and by Schroedinger, all realizing the need of a unified theory embracing gravitation, electromagnetism and the meson field involving quantum laws. Their work develops directly from the earliest modifications of Einstein's original theory by Weyl and Eddington. It is not yet evident how successful these efforts may prove to be. Relatively few people have the training and urge to analyse such work critically. But there is good evidence that in this rarefied region the adventuring in ideas is by no means at an end.

I have dwelt at some length upon changing and developing cosmological ideas to drive home the truth of the assertion that man's interpretation of the drama of the universe has been and is a powerful influence upon philosophy in its widest sense. In the more personal and intimate philosophy which consciously or unconsciously guides the actions and attitudes of individuals in society, I believe there is need of a much greater influence from astronomy. Religion, or personal philosophy, has too often been a cause of dissention, hatred and war. Why? Is it because man is apt to be like Caliban imagining Setebos altogether such an one as himself? God, at worst a supermonster, at best a tribal deity! It is astronomy which provides the far vision in space and in time, giving us the cosmic setting so essential if we would see the world in true perspective and formulate an adequate philosophy. Like Kepler we should bow down before facts and let them speak to us. One of the facts of observation is that amid all the vastness of the stellar universe we know of one small planet upon which in the fullness of time there appears this being called man to whom truth, goodness and beauty are significant, sometimes so significant that he will count not his life dear unto himself that he may pursue these. A man's philosophy must face this fact squarely, as also the facts of the physical universe where natural law operates; a man's idea of a God must be so large that this God is Creator and Sustainer of the vast universe of stars and galaxies and also in some measure akin to the mind and spirit of man, striving, struggling, failing but striving again—both literally and metaphorically, towards the light.

Queen's University,
Kingston, Ontario.
January 19, 1945.

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Astrophysics : the Riddle of Star Distances.

By A. Vibert Douglas, M.B.E., M.Sc.

THE young science of astrophysics is the direct and natural outcome of three of the oldest of all the sciences —astronomy, mathemetics and physics. Arising as it does from this triple alliance, it is endowed with the astronomical wisdom of the ages, it wields in its hand the powerful weapon of mathematical reasoning, it adapts to its use the most exquisite instruments of precise measurement that physics can devise and it strides boldly forward into new and ever wider realms of thought and realms of space with all the courage and enthusiasm of youth.

In the days of ancient Greece, Aristotle taught and Ptolemy of Alexandria perpetuated the fallacy that whereas terrestrial things were composed of four "elements"—earth, air, fire, water—the celestial bodies —sun, moon, planets and stars—were composed of a fifth element, a perfect substance, unchanging and unchangeable, the "quintessence." As long as this idea held sway in the minds of men, a science of astrophysics was impossible. For physics deals essentially with *change*—change of position, change of configuration, change of state, change of energy distribution; change of some kind or there is no physics involved, save only in one limited subdivision of physics, namely, statics; and even in statics the idea of change cannot be wholly avoided, for many of its problems are solved by recourse to the principle of "virtual work," a principle the basic idea of which is the effect of change.

The Beginnings of Astrophysics.

When Galileo turned his hand-made telescope upon the Sun and found upon its surface strange, dark markings which altered both in shape and position from day to day, he threw down and trampled under foot forever the dogma of the immutable fifth substance. There were changes on the face of the Sun, great convulsions which darkened portions of its dazzling surface; there were small satellites which moved round and round Jupiter; there were stars which blazed forth a temporary brilliance—all testified to a great law of change ruling in the heavens as well as upon the earth; and from the moment this was realized a science of astrophysics became *theoretically* possible.

When Isaac Newton passed a beam of sunlight through a glass prism and obtained thus a separation of its rays, the beautiful orderly array of spectrum colours, he achieved the first step towards making a science of astrophysics *practically* possible. For since there is no means of gaining information about the stars save that which can be read in the beam of starlight itself, the first essential to the problem of disentangling the riddle of the stars is to be able to analyse starlight.

In the judgment of F. J. M. Stratton, the science of astrophysics may be said to have had its actual beginning when in 1802 Wollaston observed that the spectrum of sunlight did not consist merely of a coloured band of light, but also of certain sharp narrow dark lines crossing the spectrum at right angles to the direction in which the colour changed from red to violet. He noted seven such lines.

In 1814 Fraunhofer made a more detailed study of the solar spectrum and mapped 574 of these dark lines. He compared also the lines in the spectrum of direct sunlight and of sunlight reflected from Venus. For his pioneer work in spectroscopy his memory is honoured by his native city in an imposing statue on the great Maximilian Strasse in Munich, while the scientific world honours him by referring to the solar lines as "Fraunhofer lines."

Forty-five years elapsed before an explanation of these dark lines in the solar spectrum was forthcoming and then it was Kirchoff whose insight enabled him to associate each dark line with a definite type of atom in the outer atmosphere of the Sun. He realized that cool gases will absorb just those radiations which they can themselves emit if raised to sufficiently high temperatures and hence they rob the out-streaming solar radiation of certain definite frequencies. Thus the resulting absorption lines give an indication of the elements composing the solar atmosphere.

Star Spectra.

The pioneer in the application of spectroscopy to starlight and the first to design a spectroscope by which he saw and studied the individual stellar spectra, and hence in a very real sense deserving of the title of Father of Astrophysics, was Sir William Huggins.

The step from the visual study of star spectra to the obtaining of a photographic record of their spectra was taken in 1872 by Henry Draper. Shortly afterwards, at the Harvard College Observatory, a line of research was initiated which has progressed unceasingly, and has led to several critical attempts to classify the stars according to their spectra, culminating recently in the completion of the Henry Draper Catalogue of over 200,000 stars, the spectra of which are classified by Miss A. J. Cannon, veteran astrophysicist of Harvard College Observatory.

Hartmann of Potsdam achieved the accurate measurement of the wave-lengths of the absorption lines in a spectrogram by means of a comparison spectrum whose lines are known and which is photographed on the same plate as the starlight, both above and below it. Thus it became possible by the precise measurement of line positions to deduce their shift towards the red or towards the violet, if such shift existed, and in this way by the application of Doppler's principle to calculate the velocity in the line of sight.

With the beginning of the twentieth century there came an almost startling advance in the realm of pure physics. The work of J. J. Thomson and others on the nature of the electron, and the investigations of Rutherford and his associates into radioactivity and the nuclear structure of the atom, led to the theoretical work of Bohr upon the hydrogen atom, and this gave for the first time a reasonable explanation of the empirical facts of spectroscopy. The elaboration of his theory by Bohr and also by Sommerfeld has greatly amplified and strengthened this physical basis for the interpretation of spectra,[1] and astrophysicists were not slow to recognize that herein lay the path to the understanding of the physical conditions prevailing in stellar atmospheres.

Luminosity and Distance.

One of the great problems of the astronomer is to determine the absolute magnitude of a star. Apparent magnitudes were placed upon a logical, though of necessity a quite arbitrary, basis by Sir John Herschel about 1859, but apparent magnitude is a function of the star's distance from the solar system as well as of the actual physical properties of the star, whereas absolute magnitude on any arbitrary scale is a function only of the physical condition of the star. By almost universal agreement the absolute magnitude of a star is taken as equal to the apparent magnitude which it would have if viewed from a distance of 10 parsecs —a parsec being the distance corresponding to a parallax of one second of arc, that is to say, the angle at the star subtended by the Sun-earth distance is one second if the distance to the star be one parsec.

If apparent magnitude be denoted by m, absolute magnitude by M, and parallax by p, a very simple relation can readily be shown to exist, as follows:—

$$M = m + 5 + 5 \log. p.$$

It is thus evident that, given m and p, it is possible to calculate M, and this has been the road of approach of the astronomer. He measured by trigonometric survey of the sky the distance of the star, or in a few particular cases deduced its distance from its proper motion, and then he calculated its absolute magnitude. The approach to this problem by the astrophysicist has been from the opposite direction. He attempts to interpret the star spectrogram in such a way as to deduce its absolute magnitude and then from this and its known apparent magnitude he calculates the parallax. Values of luminosity and distance thus obtained are called "spectroscopic absolute magnitude" and "spectroscopic parallax."

The Key to the Problem.

The first step toward the spectroscopic determination of absolute magnitudes was taken independently about the year 1914 by Hertzsprung and Kohlschütter. They found that two spectra might be so similar in general appearance as to fall naturally into the same class and yet in a few particular details exhibit such marked difference that each could be readily identified. Thus the two stars α Tauri and 61′ Cygni are both placed in spectral classification[2] K (α Tauri K5, 61′ Cygni K7) and yet close examination shows important differences in certain lines in the two spectra: for example, the calcium line (λ4455) is weak in the former and strong in the latter, whereas the strontium line (λ4215)[3] is strong in the first case and weak in the second. These facts of observation acquire a significance as soon as two things are realized: (1) α Tauri is a very luminous giant star of absolute magnitude 0.4 whereas 61′ Cygni is intrinsically faint[4] a dwarf star of absolute magnitude 8.0; (2) the calcium line (λ4455) is associated with an energy change occurring in a normal calcium atom, whereas the strontium line (λ4215) can only be produced when strontium atoms are under such physical conditions that ionization of the atoms has taken place, or in other words, that the outermost electron of each atomic system has been removed, leaving each strontium atom no longer neutral but with an excess unit positive charge. Thus, since it is known that high ionization implies a low gas pressure in that portion of the stellar atmosphere in which the "enhanced" line originates, it follows from the above-mentioned facts that high stellar luminosity is to be associated with low pressures, and a consequent increase in ionization, whereas low luminosity is implied when the spectrum shows a relatively weak ionization and a strengthening of the lines of the neutral atoms.

These were the ideas developed by the first and chief worker in the field of spectroscopic parallaxes, W. S. Adams, who by 1916 had found more than a dozen lines sensitive to changes in physical conditions in the stellar atmospheres and therefore suitable as the basis of a systematic search for a quantitative relation between the relative intensities of selected lines and absolute magnitude. Making use at first of 125 known trigonometrical parallaxes he found that satisfactory relations did exist between these factors, and in 1917 he published a preliminary list of absolute magnitudes and parallaxes thus determined. By 1920 Adams and three of his associates at Mt. Wilson had determined these factors for 1,646 stars.

Theoretical Considerations.

Since that time several others have been drawn into this work either as contributors to the theoretical basis or as partakers in the actual task of interpreting spectra with this end in view. Of the former, Pannekoek, Stewart and Eddington are the chief. Pannekoek has pointed out that the difference in the relative intensity of selected spark and arc lines (due respectively to an ionized and a neutral atom) in two stars indicates the difference in luminosity only indirectly—it is in reality a measure of the difference in the value of surface gravity on the two stars, and surface gravity is proportional to the ratio of mass to luminosity:

$$g = s \; M/L$$

—where g=gravity, M=mass, L=luminosity, and s=surface brightness, a constant for a given spectral class. Hence if a star's mass differed greatly from the average mass of stars of its class, the spectroscopic absolute magnitude would be very much in error.

The important result obtained by Eddington connecting mass and luminosity in the form

$$L = f(M) + \text{Const.}$$

has a direct bearing in this connection for it shows that luminosity may be interpreted as a function of gravity only, within a spectral class. Thus Pannekoek's main ground of criticism of the accuracy of spectroscopic parallaxes is rendered less serious.

Stewart has discussed the effects of different pressures upon radiating and absorbing atoms and has drawn attention to an important point in connection with the width of lines in the stellar spectra, namely that in giant stars, in contrast to dwarf stars, the pressure is low and the intensity of an absorption line will be greater on account of the greater depth of atmosphere; also the line will be narrower and sharper because even at this greater depth the pressure is less, there being both a lower surface gravity and a smaller pressure gradient than for a dwarf.

Solving the Riddle.

Following upon the work at Mount Wilson several other observatories equipped for taking slit spectrograms have undertaken the examination of their plates with the same purpose in view. At the Dominion Astrophysical Observatory, Victoria, B.C., this has been accomplished with marked success by Young and Harper. They based their determinations on ratios of fourteen pairs of spectral lines, some of which had already been shown suitable by Adams, others of which they found for themselves and demonstrated to be reliable. Their list of 1,105 spectroscopic parallaxes showed such a good agreement with the Mt. Wilson values that confidence in the method has been considerably strengthened.

At the Observatory of Upsala, careful determinations have been made by Lindblad and at the Norman Lockyer Observatory, Devon, two valuable contributions have been made by Edwards and Rimmer. Each worker evolves his own individual method applicable to the class of spectra he is examining, but the fact that diverse minds following diverse methods produce results which are confirmatory and harmonious is sufficient to encourage others to continue the quest and to inspire them with an assurance that the quest will not prove fruitless.

Thus is starlight being made to tell its own secrets, to reveal even the secret of the vast distances of space which separate one star from another.[5] One may well ask, What are the limits to this method or has it unlimited possibilities? The answer lies in the fact that even with the finest telescope and spectrograph it is impossible to get good spectrograms of stars fainter than a certain magnitude, and of course where no spectrogram can be obtained this method is inapplicable.

But long before this and other methods of solving the riddle of star distances have been exploited to the full, we may feel confident that the mind of man, by theoretical and by experimental advances, will have opened up new avenues of approach to a fuller knowledge of the stars—what they are, where they are, from whence they come and whither they go.

(1) In Bohr's theory of the atom an electron revolving about the atomic nucleus may move in many distinct orbits, but the atom possesses greater energy the larger the orbit in which the electron revolves. When the electron changes its orbit, energy is either absorbed or emitted by the atom according as the new orbit is farther from or nearer the nucleus. Each possible transition involves a definite change in energy, and a definite amount of energy corresponds to a definite wave-length of radiation. Hence a line of known wave-length in a spectrum may be associated with a certain orbit transition on the part of the electrons in the atoms responsible for that radiation. These relations are now known for a large number of spectral lines.

(2) Spectral classification is done on what corresponds to a temperature scale—the hottest known stars are class O, then classes B, A, F, G, K, M, in descending order of the surface temperatures of the stars. Sirius belongs to A, our sun to G, Arcturus to K, Antares to M, and so on, the range of surface temperatures being approximately from 25,000° C. to 3,000° C.

(3) λ 4215 is the spectroscopist's method of designating a spectral line due to radiation of wave-length 0.00004215 cm.

(4) On the scale of star magnitudes negative values indicate the most luminous stars, while larger and larger positive values indicate less and less bright stars. Thus Sirius of apparent magnitude −1.6, looks brighter than Aldebaran, +1.4, which in turn looks brighter than 61′ Cygni +5.6, but if all were viewed from a distance of ten parsecs, then Aldebaran would appear the brightest, absolute magnitude +0.4; Sirius would be much dimmer, +1.3, and 61′ Cygni would be too faint to see with the naked eye, +8.0.

(5) The distances thus determined range from those of our nearest neighbours in space to those stars so remote that their light travels through space for over a thousand years before reaching our solar system. When it is recalled that light travels 186,000 miles every second, the immense distances of even these less remote stars can be appreciated. The vast distance between stars can perhaps be realized if one takes as a typical case the distance from the sun to the nearest star, α Centauri—suppose the sun to be represented by a ball one inch in diameter, then the nearest star would be another ball, very much larger perhaps, but placed 100 miles away.

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Introduction for Ottawa Women's Club

For Ottawa Club

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AUTHOR-DEAN OUTLINES UNIVERSITY ROLE IN EDUCATION

Women, Men Deserve Equal Opportunities; Must Train as Co-workers in Citizenship

A. Vibert Douglas

Dean of women at Queen's University, Kingston, Ontario, since 1939 and acting professor of astronomy during the past five years, Dr. A. Vibert Douglas is internationally known in the fields of science and education. She attended McGill University where she received her B.A., M.Sc., and Ph.D. and then did further graduate work in Cambridge, England. Before assuming her present position, she was a lecturer in physics and astrophysics at McGill and a research assistant at the University of Chicago. A leader among educated women, Dr. Douglas served as president of the International Federation of University Women from 1947-1951. She has had numerous scientific papers published in Canadian, British, and U.S.A. journals and essays and articles printed in Hibbert Journal, Atlantic Monthly, *and other magazines.*

Half of the world's living, thinking, sentient beings are women. They are endowed with the same fundamental potentialities of mind and spirit as the male half—fewer geniuses among women, also fewer morons—but essentially, and equally with men, entitled to develop their potentialities as fully as their capabilities permit.

All living things find their fulfilment in growth and development. No members of the human family, whether men or women, can fail to feel thwarted, inferior, discontented, perhaps embittered, if denied as much education as their abilities warrant.

The Declaration of Human Rights recognizes the right to education: the interest, satisfaction, and pleasure of having some insight into the history of the race, the growth of knowledge, achievements in art and literature, in philosophy and science. Only through education can we live fully and wisely as individuals and as members of a community and a nation. Only by education of all members of all nations can mankind begin to achieve the ideal of intelligent, cooperative world citizenship.

Aims of Education

To impart some knowledge and understanding of the true, the good, the beautiful, and to train people to think on these things and to plan their actions in accordance with them are the aims of education. These are the bases of wisdom—wisdom to meet the tremendous personal and group problems of today and tomorrow.

Over the greater part of this continent wide opportunities now exist for women to pursue university training. However, educators must be continually on their guard against the pressure from various directions to water down university courses to high school standards of spoonfeeding, and to reduce the hard discipline of intense academic courses by the inclusion of optional subjects of a pseudo-academic or a pseudo-artistic or purely technical nature—courses which may be valuable as community center or club activities but which have no rightful place within a university.

Must Provide Inspiring Teachers

The first responsibility of a university to its students is to provide teachers who have spiritual as well as intellectual qualities and who have a contagious enthusiasm for their subjects. No one can measure the influence of an inspiring teacher, a man or woman who has "a sincere and kind familiarity with wisdom." Nor can one over-estimate the influence of the scholar who is wringing forth the secrets of his chosen field, without narrowing down his sympathies, losing his perspective and stultifying his humanity.

Our schools and colleges must provide a mental discipline, a training in basic logic, a suspicion of vague generalities: the ability to discern the truth. Bacon's requirements for the man of science are worth holding before students in every faculty, "the desire to seek, patience to doubt, fondness to meditate, slowness to assert, readiness to reconsider, carefulness to dispose and set in order, . . . a man that hates every kind of imposture." These are amongst the highest characteristics of mankind and call as loudly for inclusion in a student's philosophy of life as do the measurable facts of the physical universe.

The university has a responsibility to encourage its students to formulate a philosophy of life, a working hypothesis for living which will stand four-square to the winds of ignorance, indifference, cynicism, and sentimentality.

Must Foster an Active Imagination

The university should foster an atmosphere condusive to stirring and stretching the imaginative faculty in every student. Imagination is fundamental to the appreciation of what has been achieved in literature, in art, in music, in every form of science, in economics, in philosophy; creative imagination is the mysterious force, the trigger action, which impels the mind of man across the frontier of knowledge and achievement into new realms of thought and new modes of expression.

Let the universities plan their curricular and extra-curricular programs to jog the mind out of pedestrian paths so that there may be more students whose imaginations "go forth to uncurbed glory."

More and more demands are being made on university graduates to play a part in local community affairs and international affairs. It is the duty of the university to encourage recognition of this fact and to provide some training for such service. This can be done through student self-government, public affairs clubs, visiting lecturers, and in other ways. It is not enough today to be a specialist in some one line; one must also be an active working citizen and an intelligent student of conditions in the world, capable of playing a part in moulding an honest, far-visioned public opinion.

More and more, too, university women must be willing to run for public office, to serve on school boards, town councils, and in legislative bodies. In preparation for such service, the universities must teach their men and women students to pull together as citizens, irrespective of sex, co-workers equally concerned in knowing the facts, righting injustices, seeking solutions to the problems of mankind and combatting intolerance and apathy.

Must Teach Internationalism

The universities have a responsibility to teach internationalism. This becomes more urgent than ever before as weapons of destruction become more appalling and far-reaching in their dire consequences upon the human race, born and unborn. Selfish isolationism and intolerance can only be overcome by knowledge and a realization of the indebtedness of any one nation to many other nations.

Not only through history, economics, political science, and religion stressing the brotherhood of man, can students be made more world minded. By proper emphasis on the development of every subject taught within the halls of a university, students should be constantly reminded of their debt to the great thinkers of other nations. It is not enough to begin thinking in such terms at the university level, but it is at the universities that this realization must be consciously directed to the challenge of world citizenship.

Educated Must Assume Responsibility

Without far-seeing, courageous, honest leadership and dynamic, enlightened public opinion, it is not beyond possibility that dire calamity may overtake the human race. On the educated men and women of many countries rests the responsibility of developing not only the science of furthering knowledge but the art of using it for constructive not destructive purposes.

The universities must strive to give their students the wisdom and perspective which come from a study of the past, the courage and vision to foresee a great and good future, and the knowledge and skills to enable them to use the present—each instant as it comes—so that their highest ideals, as individuals in their homes and communities and as world citizens, may be brought nearer and nearer to realization.

A. Vibert Douglas

Education | **PROFESSIONAL**

Teachers Need Spiritual Values, Insight

The air of freedom supplies the only context for moral discrimination and the pursuit of true wisdom, yet the changing conditions of man require changing attitudes and ideas. All of us, whether we teach or not, have jobs which need to be done if education is to reach its ultimate goal.

No Room for the Lazy

There is no room for the lazy, the incompetent, or the intellectually sterile in any phase of our school system. Whether we are trustees of colleges or universities or members of citizens' committees for public schools, we ought to be more than a buildings and grounds committee. Our students ought to be more than mere receptacles for opinions and facts. Our administrators ought to do more than "manage" staffs and carry their honorary degrees with dignity. Our teachers must be more than animated card files. The job is not for one group. All of us are members of some part of the academic community. Only by working together can we keep the quest for truth alive!

Teachers Must Recognize Role

What can the teacher do? She can recognize her role:

1. To present facts and ideas so they will be heard and respected;
2. To believe as rigid fact that her profession includes giving information *and* guidance in character development;
3. To realize that teachers are but temporary custodians of the thoughts and actions of their students, but that even a partial effect can be important;
4. To develop the capacity to create values, and the passion to defend values;
5. To develop the essential qualities of clarity, curiosity, insight, incisiveness, integrity, good taste, good will, conviction, responsibility;
6. To reflect a sense of adventure about life in general and about books and ideas in particular;
7. To realize that cynicism at best is a waste of time; at worst, a dangerous and potentially fatal disease for individuals and civilizations both;
8. To believe, finally, that teaching is the means by which the future is formed and the best teacher is the one who is able to supply a coherent structure which is definite enough to meet a continuous challenge and yet loose enough to keep the quest for truth alive.

Ethel Barber

Deterred from a career as a concert pianist by several accidents to her right hand, Dr. Ethel Barber took a B.A. at Milwaukee-Downer college majoring in mathematics, financial economics, and speech. While teaching speech in Milwaukee, she met her future husband, and after her marriage moved to Evanston. She was an organizer and charter member of the North Shore branch of A.A.U.W. and served as its chairman of arts, memberships, literature, program, and president (1949-51). She was granted her Ph.D. by Northwestern in 1947 and has since conducted private courses in the drama and travelled widely as a lecturer.