A Vibert Douglas "Astronomy in a World at War" Publication 84.

OMCD. from A.

ASTRONOMY IN A WORLD AT WAR

BY

A. Vibert Douglas

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

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 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.*

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:

> 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.*)

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.

---

*NOTE: Recent work from D.A.O. and from U.B.C. points to a confirmation of the work of Foster and Douglas on the interpretation of helium profiles by Stark effect.

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 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.