Livens took a prominent part in the general administration of the University and was much interested in student problems. For many years he was a member of the house committee of the Students' Union, where his wise counsel was much valued. As adviser and examiner in mathematics to the Central Welsh Board, he exercised a great influence on the teaching of mathematics in secondary schools; he also took a great interest in the mathematical courses in the Welsh Training College for Teachers. For many years he was an examiner in mathematics for the University of London.

He is survived by a widow, a daughter and a son. He was elected a Fellow on 1924 February 8.

H. SPENCER JONES.

TAKEHIKO MATUKUMA, a professor of the Tohoku University at Sendai, died suddenly on 1950 January 14.

He was born on 1890 March 18 at Karatsu in Saga prefecture, Japan. He finished the course of astronomy in the Tokyo University in 1913, but as there was no position vacant in astronomy he taught for several years at High Schools and in 1920 he was first appointed an assistant professor in the Tokyo University. In 1924 he changed to the Tohoku University and was made a professor of astronomy in 1934. From 1925 to 1927 he stayed in Europe and was present at the Cambridge meeting of the I.A.U.

Professor Matukuma's researches were mainly in the problem of three bodies and in relativity theory. In his later years he was eagerly engaged in the mathematical problems associated with the Schmidt camera. He liked travel and observed the solar eclipses in 1936 at Hokkaido, in 1941 at Paicho, China, and in 1943 at Hokkaido. At the 1941 eclipse he tried to verify the Einstein shift of stellar images and was successful. In addition he was a skilful teacher and published several lectures in book form. He was elected a Fellow on 1926 January 8.

Y. HAGIHARA.

EDWARD ARTHUR MILNE was born at Hull on 1896 February 14. He was the eldest of the three sons of Sidney Arthur Milne, headmaster of St. Mary's Church of England School, Salthouse Lane, Hull. The family lived at Hessle, where Milne began his education at the National School. Afterward he went to Hymer's College, Hull, where the headmaster, C. H. Gore, himself a gifted mathematician, inspired Milne's love of his subject as a schoolboy. Milne remained on terms of affectionate friendship with him for the rest of his life.

In 1914 Milne entered Trinity College, Cambridge, as a mathematical scholar. He spoke in later years of the wonderful sense of intellectual emancipation which he there experienced. No doubt his experience was a common one of young men entering the life of a great college and university. But, being constituted as he was, Milne must have savoured it with an intense awareness far above the average. He could see vistas of intellectual achievement stretching out before him, and it is small wonder that he always preserved a special regard for those who at that time directed his gaze in such directions. Among these he used to name particularly his director of studies E. W. Barnes, S. Chapman and G. H. Hardy.

The First World War had started when Milne went up to Cambridge, and, despite all his academic aspirations, he was anxious to serve in any way open to him. His defective eyesight excluded him from active military service. He therefore eagerly accepted the invitation of A. V. Hill early in 1916 to join the Anti-Aircraft Experimental Section (as it was afterwards called) of the Munitions Inventions Department which Sir Horace Darwin had asked Hill to form. He forthwith became, in Professor Hill's words, " an essential element in our party and did some of the finest work we achieved ". The party came in course of time to include a big proportion of the most able mathematicians in the country as well as several distinguished physicists.

In obituary notices of R. H. Fowler (*Obit. Notices, Roy. Soc.*, **5**, 61, 1945–8; *M.N.*, **105**, 80, 1945) and of H. W. Richmond (*Obit. Notices, Roy. Soc.*, **6**, 219, 1948–9), Milne himself has recorded a vivid impression of the A.A. Section and of the atmosphere in which it worked. No other account could show so well, as the incidental indications he there presents, what effect those years had in developing his powers of mind and personality and in determining the trend of his interests.

The work was mainly on ballistics and sound-ranging; both subjects naturally involve many problems concerning the Earth's atmosphere, and this fact was probably the start of Milne's interest in atmospheric theory in general. He shared in the mathematical, computational and practical parts of the work, displaying great capacity in all of them. During gun trials, he was sometimes sent up in an aircraft as high as it would go to measure pressure and temperature at various heights; he had a talent for getting the R.F.C. pilots to do what was wanted. So as to ensure against his being conscripted and transferred from this sphere of service, he was commissioned as a Lieutenant, R.N.V.R. He worked mainly at Whale Island, Portsmouth, but spent some months in France with the Officer commanding the Anti-Aircraft Artillery of the First Army, who found Milne's assistance most valuable. For his war service he was awarded the M.B.E.

At the end of the war Milne wrote a volume on sound-location as one of three text-books asked for from the Section by the War Office. There also resulted from his war-work his first published paper (with R. H. Fowler) on " Siren harmonics and a pure tone siren ", *Proc. Roy. Soc.* A, **98**, 414, 1920.

In 1919 Milne returned to Cambridge and was forthwith elected a Fellow of Trinity College largely on the strength of reports by his war-time superiors. In the following year he accepted the invitation of H. F. Newall to become Assistant Director of the Solar Physics Observatory: it was this step that made him an " astronomer ", in a very broad sense of this term, for the rest of his career. From 1921 to 1925 he was University Lecturer in Astrophysics. In 1924 he was appointed also to a lectureship in Mathematics at Trinity College and resigned his post at the Observatory. His lectures were clear and stimulating and he took an exceptional interest in undergraduates who attended them and in those who had him for their director of studies.

From 1925 to 1928 Milne was Beyer Professor of Applied Mathematics in the University of Manchester in succession to his close friend S. Chapman. He was very happy in this position and put his heart and soul into his work. He entered fully into the academic, scientific and administrative activities of the university and earned the highest esteem of his colleagues and students. Many lasting friendships resulted from this intercourse.

In 1928 Milne was elected first holder of the Rouse Ball Professorship of Mathematics at Oxford and in 1929 to a Fellowship at Wadham College.

He retained these positions for the rest of his life. In a separate part of this notice Professor H. H. Plaskett gives an account of his time at Oxford.

During the Second World War, from 1939 to 1944, Milne had leave of absence from Oxford to serve with the Ordnance Board, working for the most part at Chislehurst, Kent. His work dealt with ballistics, the analysis of armour-piercing experiments, rockets, sound-ranging, and the optimum distribution of A.A. guns. To a considerable extent, it was a natural resumption of the work he did in the First War. His theoretical work on stability of projectiles and on armour piercing is still regarded as the latest achievement in these subjects. Once again his astonishing range of abilities made a deep impression upon all those with whom he worked.

Milne was twice married. His first wife whom he married in 1928 was Margaret (" Margot ") Scott, daughter of H. F. Campbell of Dornoch and niece of Professor E. Fiddes of Manchester. There were two daughters and a son of this marriage. Soon after the son's birth in 1938, Margot Milne died in exceedingly distressing circumstances. Milne's second wife was Beatrice Brevoort, daughter of the late William W. Renwick of Short Hills, N.J. She was an American whom he had met on board ship on the Atlantic just before the war and who, after the outbreak of war, made a heroic journey to this country for their marriage in 1940. They had a daughter born in 1943. In 1944 they moved back to Oxford, but during the course of their removal their war-time home near Chislehurst was destroyed by a flying bomb. This climax to the rigours of the war years in a strange country overstrained Beatrice Milne's gallant spirit and led to her tragic death in 1945.

In other respects, too, Milne's life was singularly overclouded by tragedy. His father died suddenly in 1921 at the age of 53 and left him to help to support his family. In 1923 he suffered an attack of epidemic encephalitis, a disease which made only a temporary appearance in England about that time. He was looked after by W. Hartree (father of D. R. Hartree), and other Cambridge friends helped to see that he got the best possible attention. Though he made a good recovery he did not escape the late after-effects which gave rise from about 1945 to nervous disturbances producing rigidity of muscles and tremor. Added to this, his heart became affected and for some years he was a sick man. He died suddenly in Dublin, where he had gone to attend the special meeting of the Society, on 1950 September 21.

Milne received many honours in recognition of his scientific achievements. They included the following awards and appointments: 1922 Smith's Prize; 1926 F.R.S.; 1929 Bakerian Lectureship, Royal Society; 1935 Gold Medal, R.A.S.; 1937–9 President of London Mathematical Society; 1934 Hon. D.Sc. University of Amsterdam; 1941 Royal Medal, Royal Society; 1943–5 President of R.A.S.; 1943 James Scott Prize, Royal Society of Edinburgh; 1945 Bruce Medal, Astronomical Society of the Pacific; 1946 Hopkins Prize, Cambridge Philosophical Society.

In appearance, Milne was small and slight, but, so long as his health remained, he could be said positively to exude vitality. His features were often set in intense concentration but in conversation they became wonderfully mobile and expressive. They became overspread with impish delight at any witticism that appealed to him.

In personality, he was extraordinarily richly and completely endowed. He had a phenomenal gift for making and keeping friends of all ages. His friendships played a great part in his life: they were maintained by his natural loyalty as well as by his punctiliousness in correspondence and, above all, by his depth of human understanding. Some measure of this can be gauged from the obituary notices he wrote about some of the men he had known, R. H. Fowler, G. H. Hardy, J. H. Jeans, A. E. H. Love, H. F. Newall, H. W. Richmond, in particular. Each of these notices was a masterpiece of its kind and they have come to be counted among his notable achievements. With all their insight and skill of expression, they were composed in very short times, with few aids to his memory, and, as it happened, often during air-raids or other difficult circumstances.

His loyalty and understanding extended not only to individuals but to any institution with which he was associated. He had a most perceptive appreciation of the traditions of each of them and exerted himself unsparingly in their support. He was always ready, too, to enjoy any sociabilities connected with them. Aided by "photographic" powers of observation and memory, he took delight in literature and in art, especially architecture upon which he showed himself very knowledgable, and also in natural scenery. All who are in a position to know will agree that, notwithstanding all his brilliance in so many directions, he was at his best as a devoted father among his own children.

Milne's courage and will-power were superb. The tragedies of his life could have befallen no more sensitive soul: he escaped no detail of their poignancy. Besides all this, it was his fate that much of his work should be of a controversial character while the satisfaction he could derive from what he did depended to an unusual degree upon its gaining sympathetic consideration by others. Nevertheless, distracted as he was by private grief and often disheartened by what he regarded as almost wanton misunderstanding of his ideas, he persevered with manful determination towards the objectives he set himself. He was essentially a religious man; faith and courage gained the victory in each succeeding struggle of his life.

In reflecting upon Milne's scientific work, certain personal characteristics have to be taken into account. His intellectual make-up was predominantly that of a mathematician. Early in his second year at Cambridge, G. H. Hardy described him as one of his very best pupils in pure mathematics, and it is usually thought that, had it not been for the war, he would have become a pure mathematician of the Hardy school. The present writer is inclined to think, however, that Milne's special satisfaction was in the power and generality and also in the "pattern" of pure mathematics rather than in refinements of mathematical analysis. These characteristics were always present in the mathematics he used for his own investigations. But in his kinematic relativity, for instance, he did not usually remark that his functions were assumed to be single-valued and to be restricted in other ways, as a more analytically minded mathematician would automatically have done.

Milne himself considered that there were gaps in his knowledge of routine elementary mathematics in consequence of his not having completed the course for the Tripos at Cambridge. It is hard to see any evidence of this in his work. He was, of course, the first to admit that in compensation his war-work with A. V. Hill and R. H. Fowler had given him an unrivalled training in methods of research. In passing, one cannot help suggesting that the singular circumstances of his early career did, however, have a psychological effect which he did not realize. As a young undergraduate he went to work with men who were mostly " dons ", with all that that status denotes to the undergraduate. In his own subconscious mind, this distinction of status must have become artificially stabilized for the next three and a half years. Ever afterwards he seemed to retain traces of the undergraduate attitude towards other workers.

Milne probably wished to be regarded as neither a mathematician nor a scientist, in the senses in which these terms are commonly understood, but as a " natural philosopher ". At first he contented himself with taking certain of what he considered the principles of natural philosophy to guide him to what physical problems it seemed desirable and profitable for a mathematician to tackle and to the way he should set about them. It is significant that his inaugural lecture at Oxford (1929) was entitled " The Aims of Mathematical Physics " and his second Presidential Address to the Society " The Natural Philosophy of Stellar Structure ". At this stage in his work, if he shared the gratification of other scientists in accounting for any particular observed phenomenon it was from a somewhat different viewpoint from theirs. He liked to regard it as illustrating some general " theorems " of mathematical physics rather than as a solution of a particular puzzle. The challenge to him was not to solve the puzzle itself but to build up the system of theory which would naturally lead to the solution of some class of problems to which the particular one would be found to belong. At a later stage he tended to the view that a more direct application of " philosophical " principles could lead to the discovery of natural laws possessing a status superior to that of any hitherto known. However, he scarcely went so far in this direction as some of his critics supposed. I think it was his developing philosophical attitude that led him to devote the last fifteen years of his life to the development of kinematic relativity, rather than that his discoveries in this subject produced his philosophical attitude. He came to believe, as he said in a letter in 1942, " that philosophy is the summit of scientific endeavour and that, unless one makes for oneself a philosophy of the ultimate nature of reality, one's science is meaningless ". I think, however, that philosophy was for him, by definition, that which would supply him with what he called a " meaning " for his work. Multitudinous as were his endowments, I do not think that they included the power to grapple with the problems of professional philosophy.

Milne's work on astrophysics, which was largely completed by 1935, was of such a character that its definite contributions became rapidly assimilated in the subject. Given the necessary space, it would be a comparatively straightforward matter to estimate its value in the light of subsequent developments which have already taken place. His later work on kinematic relativity is much more difficult to assess. But he has left a full account of it and in due course its value will also become apparent. What it seems most vital to put on record here is the tremendous influence which he exerted during a long and eventful period in the development of modern astrophysics and cosmology. This was at first most widely due to his published papers rather than to his leadership of any "school". From 1921 onwards these papers appeared in quick succession and ranged over a great extent of the rapidly developing scope of astrophysics. The very speed with which they must have been composed meant that they bore with them their author's zest for discovery. They were full of ideas and they inspired the conviction that here were subjects worthy of being studied and upon which there remained plenty of useful work to be done. It would be inappropriate here to give names, but one knows that many of those who are now in the forefront in astrophysical research are glad to acknowledge that their early enthusiasm was enlisted by Milne's writings. Somewhat later, he was able also to exert a more direct influence upon a succession of distinguished pupils at Oxford. Some of those whom he influenced in one way or another proceeded to obtain results of more permanent value than his own. However, their work would not have been done but for the stimulus he gave them. The history of astrophysics during the past twenty or thirty years would have been very different had it been denied the inspiration of Milne's own brilliant genius.

The first main phase of Milne's work was the one that is of greatest proved value. It dealt, broadly speaking, with "atmospheric" problems in astrophysics and was naturally concerned with the two main classes of problem that arise, those of the transfer of radiation through an atmosphere and those of the state of ionization of the atmospheric material. Milne made major contributions in both categories. But the general theory has of course to combine the results of both types of investigation and the combination produces its own problems concerning the detailed interaction of matter and radiation: Milne examined many of these with great thoroughness and elucidated many points of considerable subtlety.

The foundations of the theory of radiative transfer through a scattering atmosphere had been laid by A. Schuster in 1901 and those of the theory of an absorbing atmosphere in radiative equilibrium by K. Schwarzschild in 1905 and 1915. Milne's first undertaking was to recast, extend and combine their investigations and to provide approximative methods for solving the resulting equations of transfer. Part of this work he described in his first paper to the Society in 1921 and others following soon afterwards, but the main account is in his well-known paper in *Philosophical Transactions* 1922 (this itself being part of his Smith's Prize Essay). Amongst other results, he derived expressions for the emergent flux and the law of darkening towards the limb as functions of the frequency of radiation for an atmosphere in radiative and local thermodynamic equilibrium and in which the opacity depends on frequency. Milne showed that his work made it possible to use the observations of the continuous spectrum and limb-darkening for the Sun in order to infer the dependence of the opacity on frequency. His method is still employed to obtain this information and thus to provide the evidence for ascribing the opacity mainly to the negative hydrogen ion. In fact, as Professor Chandrasekhar has remarked to the writer, Milne might easily have predicted the existence of a constituent in the solar atmosphere possessing just those properties which we now know the hydrogen ion to possess.

For an admirable account of this phase of Milne's work one cannot do better than to refer to the address* delivered by Professor F. J. M. Stratton as

* F. J. M. Stratton, *M.N.*, **95**, 421, 1935.

President on the award to Milne of the Gold Medal " for his work on Radiative Equilibrium and the Theory of Stellar Atmospheres ". Professor Stratton dwelt deliberately upon the physical significance of the work but, as he indicated, it contains much that is of mathematical interest as well. Here it may suffice to allude only to one or two of the main achievements. Perhaps the greatest was that of the joint work of Fowler and Milne in 1923–4 on the intensities of lines in stellar spectra. They did not claim to add any new basic idea to those that had shortly before been contributed by M. N. Saha. But, by exploiting more powerful methods of statistical mechanics to obtain a theory of the maximum intensity in the spectral sequence of any particular line, instead of its marginal appearance, they obtained more trustworthy estimates of the temperatures and pressures in stellar atmospheres. More than any other single investigation, their work established the modern view of the orders of magnitude of these quantities.

This work was probably the most that could be achieved without employing a detailed theory of the formation of stellar spectral lines and dealing with the relevant problems of radiative transfer. Milne had all along played a leading part in the development of this side of the work, though by this time several others were also making important contributions. The culmination of his own contribution was his Bakerian Lecture of 1929.

By this time Milne had got the ideas that he thought would revolutionize the theory of stellar structure (the material of his paper read at the November meeting of the Society that year) and had set his heart upon announcing them to the world in his Bakerian Lecture. He had consulted Eddington whose instincts told him that Milne's conclusions could not be valid and who advised Milne to withhold the work for reconsideration for at least six months. With grave reluctance, Milne acquiesced and, only three or four weeks before the Lecture, resolved upon the subject he actually presented, " The structure and opacity of a stellar atmosphere ". Working at speed, he completed the extensive calculations required for the results as they stand in the published Lecture. The outcome was perhaps his most useful paper after that of 1922. He showed how the concept of the " concentration " of a particular atomic species in a stellar atmosphere, which had been used by Fowler and himself, could be replaced by that of the " number of atoms above the photosphere ", which could in turn be related to a precisely defined measure of the intensity of a line produced by them. He then showed how a comparison of the theoretical value of this intensity with observation would yield an absolute value for the continuous absorption coefficient of the atmosphere. He proceeded to give the first reliable quantitative theory of the absolute magnitude effect upon the line intensities. Finally he explored the physical state of the photospheric layers more extensively than ever before. In describing his results he acknowledges what the present writer remarked at the time, that they would require modification if the predominant abundance of hydrogen were substantiated. But the general concepts he introduced stimulated many of the most important subsequent developments.

In company with other astrophysicists at the time, Milne failed to understand how Eddington could (within fairly narrow limits) calculate the luminosity L

of a star of given mass *M* without any knowledge of the source of the luminosity. It seemed to Milne that, in the absence of such knowledge, *M* and *L* had to be treated as independent variables, in fact that the fundamental problem of stellar constitution was, given material of any assigned mass *M* capable of radiating at any assigned rate *L*, to calculate the equilibrium configuration of the resulting "star". Then in 1929 he was seized with the conviction that he had discovered the flaw in Eddington's work, and, as a result, the way to solve the fundamental problem as he saw it. Since his preliminary calculations gave startlingly new conclusions about stellar structure—gaseous stars with radii of the order of a parsec, partially non-gaseous stars with central temperatures of the order of 10^{12} degrees, and so on—he naturally considered that he was on the threshold of the greatest things in his career and he went to work on them with consuming energy. During the next few years he published papers totalling some hundreds of printed pages and containing the results of tremendous efforts in computation, devoted to the development of these ideas.

Milne thought that Eddington had been led astray by making his results depend upon a singular solution of Emden's differential equation. When Milne realized that there are infinitely many other solutions he concluded that, in a general way, these must correspond to the existence of stars of all other luminosities besides the (almost) unique one that Eddington had singled out for consideration. He thought that Eddington had failed to discover these other possibilities as a result of having assumed the gas-laws to hold throughout, having integrated out from the centre and having used only approximately correct boundary conditions at the surface.

Milne argued that we can assume the gas-laws to apply only sufficiently near the surface, that it is necessary to integrate inwards from the surface, and that, since the mathematics then shows the impossibility of the gas-laws continuing to apply for general values of *M*, *L*, it is necessary to complete the model with zones of material obeying other equations of state. He proceeded to give elaborate discussions concerning the maximum amount of information about the internal structure of a star that can legitimately be inferred from comparisons with observation.

It may perhaps be said that Milne's approach was more logical but less scientific than Eddington's! What Eddington had done was not, of course, to *assume* that the gas-laws hold good throughout any actual star, but to work out the properties of a gaseous model star of given mass *M*. He found that for this to be in equilibrium with any radius *R* it must possess a certain luminosity *L*, which he found to depend only insensitively upon *R*. To his own surprise he found that his calculated value of *L* (for any plausible value of *R*) agreed well with the observed value for all stars other than white dwarfs. But when he considered the internal conditions of his model as found from his calculations, he was able to show that matter must in fact be gaseous under these conditions. Eddington had therefore a self-consistent model that agreed satisfactorily with observation. He was justified in his belief that the mechanism of energy-generation would be found to be compatible with his results. For all that is required is that this mechanism should depend upon a high power of the temperature. The star can always then find a radius *R* such that the rate of energy-generation balances the rate of emission *L* from the surface, and this value of L, as Eddington discovered, depends only weakly on the value of R. As we now know, thermonuclear processes of energy-generation do satisfy the requirement.

In retrospect, it is surprising that Milne did not see that his work actually strengthened Eddington's position. For Milne's more general approach made it possible explicitly to exclude cases not considered by Eddington.

One is referring here to Eddington's model in a generic sense. Obviously, a great deal has needed to be done since Eddington's own work. While it cannot be claimed that any of the subsequent advances were made by Milne himself, it is fair to assert that a number of them are due to his having either provided the stimulus or the required mathematical framework. And it may be added that he had himself reached a position in which he could have derived some of the results by merely reversing certain of his arguments.

In 1932 Milne proffered the suggestion that the physically obscure phenomenon of the "expansion of the universe" is perhaps not essentially different from the inevitable dispersal of, say, a gas-cloud liberated in free space. This simple observation was destined to divert his main interest from astrophysics to cosmology and relativity and to the consideration of the status of laws of nature.

Although it was demonstrated that the effect to which he had called attention is taken care of by general relativity, Milne was convinced that he had found a clue to an entirely new approach to cosmology. If the broad features of the expanding universe can be explained by elementary principles of pure kinematics, he argued, is it possible that *all* its properties result from its kinematics and nothing else ?

Despite Milne's assertions that no-one was more astonished than himself by subsequent developments, one must credit his audacious imagination with showing him from the start that something big could be expected of his venture. This proved to be the creation of "kinematic relativity". Whatever its ultimate scientific value, as an intellectual creation of a single mind it is almost unique in character. For its main construction, Milne followed no traditions, borrowed no concepts, and found no ready-made mathematical machinery.

Briefly expressed, Milne constructed a theoretical model of the universe in which observers are endowed with specified rudimentary means of observation, the description of this universe being expressed entirely in terms of the observations made by them. As a consequence of his specification of the system, he showed that there exists (in a mathematical sense) a fundamental set of equivalent observers. Assuming the cosmological principle that each fundamental observer must see the same "world-picture", he established many properties of this world-picture and certain properties of the motion of a free test-particle. From the latter he inferred, without further assumptions, that the phenomenon of gravitation is exhibited in his model and that it follows what can be interpreted as the inverse square law.

Milne then proceeded to develop systems of dynamics and electrodynamics. These were framed so as to be consistent with the foregoing work, but were otherwise of a rather formal character. His last paper, which he was to have read in Dublin, claims to show that his work predicts effects much like those resulting from Blackett's hypothesis concerning the magnetic fields of rotating masses.

The development of the work is recorded in a long series of papers; various aspects are reviewed in several of Milne's published addresses, including the first of his Presidential Addresses to the Society (1944); systematic accounts are given in his books *Relativity, Gravitation and World Structure* (1935) and *Kinematic Relativity* (1948). These are all pervaded by the sense of exhilaration which Milne experienced in his pursuit of the work.

Despite the stamp of inspiration borne by it, kinematic relativity has attracted comparatively little scientific interest and considerable adverse criticism. One owes it to Milne to make some attempt to analyse the reasons.

Kinematic relativity is an alternative to general relativity. Now general relativity as a theory of gravitation (i. e. ignoring electromagnetic phenomena) is generally considered to be highly satisfactory. We cannot, however, conceive that any theory is incapable of being improved upon. But the structure of general relativity is such that it admits of no *slight* re-adjustment. Therefore any possible improvement presumably demands a radically new approach.

Milne did make such an approach. Moreover, he made it in what ought to be the most promising way, for he worked directly in terms of "observables". In fact his analyses of timekeeping and related problems, along with the contributions of G. J. Whitrow, do seem to denote real progress in the treatment of space-time. This work has already led A. G. Walker to a far-reaching analysis of the foundation of relativity theory.

Such work, however, is apt not to attract much notice unless it has some novel physical consequences. Kinematic relativity has hitherto been somewhat unproductive of these. I believe this to be because, apart from the fundamental parts just mentioned, it depends upon the use of a strict cosmological principle. This was explicit in the earlier presentations but tended to become obscured in *Kinematic Relativity*. Now the universe manifestly does not conform strictly to a cosmological principle—at best it conforms only statistically. But a statistical property would not meet Milne's requirements as he developed the theory. Therefore it seems that kinematic relativity has been developed so as necessarily to yield not much more than the analogues of some of the particular models already treated by the general relativity theory of the expanding universe, and to be in its existing form incapable of dealing with more detailed problems, e. g. planetary orbits. Moreover, the analogues of the general relativity models are almost the same as the latter and this is one reason for the belief that the theory gives nothing of fresh physical interest. But this impression is not entirely justified. For Milne's fundamental particles (galaxies) may be regarded as a *discrete* set while the general relativity models represent a completely smoothed-out universe. Consequently such properties of the universe in the large as depend characteristically upon the discreteness of the galaxies cannot be revealed by the latter models but may to some extent be revealed by Milne's methods.

Much might be written about Milne's claims regarding the significance of his work. If there was an occasional hint of extravagance in them, it was only human and not to be derided by those of us who have adventured less in pioneering thought. It seems to the writer that an analysis of his claims shows that many of them were not essentially different from those made on behalf of any physical theory. The remainder seem to amount to saying that in his theory certain of the initial propositions (axioms) concern the observers instead of the system observed; this can be recognized as a progressive feature.

Besides the main lines of work already mentioned, Milne wrote extensively upon many other topics. These included the physics of the Earth's upper atmosphere (with S. Chapman, 1920), the escape of molecules from an atmosphere (1923), the chromosphere and the ejection of high-speed atoms from the Sun (1925–6), to mention only a few of the best-known and most frequently quoted investigations; problems in thermodynamics, statistical mechanics, pulsating stars, to give instances of his recurrent subsidiary interests. Also, besides the books already mentioned, he wrote "Thermodynamics of the Stars", published as part of the *Handbuch der Astrophysik* (Berlin 1930), which is a very fine text-book of radiation theory, and *Vectorial Mechanics* (1948), a book whose value is becoming increasingly appreciated and is likely to establish itself as a minor classic. These illustrate Milne's unfailing mastery of orthodox applied mathematics, which was probably what stood him in such good stead in his two spells of war-work. Together with the evidence of his early work, they irresistibly suggest that his true genius lay in the most skilful mathematical handling of well-understood physical processes. Had he imposed more check upon an unacknowledged yearning after revolutionary concepts, he would probably have surpassed even the brilliant achievements that now stand to his credit. Milne wrote, too, a life of J. H. Jeans, which is still in the hands of the publishers. At the time of his death he had just completed *Modern Cosmology and the Christian Idea of God the Creator*, which was the text of an intended course of lectures on the Edward Cadbury Foundation in Birmingham.

He was elected a Fellow of the Society on 1921 February 11 and served on the Council 1923–27, 1928–34, 1935–39, 1943–48, being a Vice-President 1936–38, 1945–47 and President 1943–45.

The writer gratefully acknowledges much information (not all of which has there been space to include) about Professor Milne's life supplied by his brother Mr P. S. Milne, Professor E. D. Adrian, Sir Lawrence Bragg, Professor S. Chandrasekhar, Brigadier P. S. Gostling, Professor A. V. Hill, Professor L. J. Mordell, Professor F. J. M. Stratton and Dr G. J. Whitrow.

W. H. MCCREA.

Milne was elected to the newly founded Rouse Ball Professorship of Mathematics in 1928, and took up his appointment at the early age of 33. The other Professor of Applied Mathematics was A. E. H. Love, whose days of active research were then nearly over, though his lectures were still the most lucid, as they were among the most popular in the University. Milne's arrival, however, brought new life to the subject, and he soon attracted to himself some of the more able of the young mathematicians. His colloquium, an innovation in this subject at Oxford, was attended by these students and by many senior members of the University who found in Milne a stimulating leader with an unusual gift for seeing a subject in a new light. On a famous occasion Henry Norris Russell, in Oxford for the delivery of the Halley Lecture, read a paper on the advance in periastron of Y Cygni, and the ensuing discussion, which arose from the contrasting physical approach of Einstein and the mathematical insight of Milne, lasted late into the night. The measure of Milne's achievement at Oxford is to be found in the applied mathematicians who took their doctorate under his supervision; these include Camm, Cillié, Cowling, Getting, Prasad, Walker and Whitrow, to mention only some.

Characteristically Milne entered fully into other sides of the life of the University and was at the same time a devoted Fellow of Wadham, the college to which his professorship was attached. He was of course a member of the Sub-Faculty of Mathematics, and for a number of years its chairman. In this capacity he played an important part in securing rooms for the Mathematical Institute in the newly opened wing of the Radcliffe Science Library, and won a hard-fought action to secure for mathematicians the right to smoke in these sacred precincts. He was almost continuously an official member of the Board of Faculty of Physical Sciences and for the last two years of his life its chairman. He was also a member of a somewhat dull body, the Museum Delegates, and conscientiously attended its every meeting twice in each term. He dined frequently and regularly in College, and of his life there it has been recorded that " he was anxious only to take his share of duties and responsibilities ". For some years after the war he was the College Librarian, and was responsible, almost single-handed, for cataloguing and re-arranging its books.

The appointment at Oxford coincided with a change in the direction of Milne's interests. Up to that time, as Professor McCrea has set forth so clearly, Milne had concentrated on the problems presented by stellar atmospheres. He was among the first to realize that the concept of radiative equilibrium entailed the constancy of the net flux of radiation through the atmosphere, he was the first to give the integral equation for this net flux, and he used its constancy to obtain a greatly improved approximation to the dependence of temperature on optical depth. In the second paper communicated by him to the Society he gave independently, and at the same time as B. Lindblad, the spectral distribution and the darkening to the limb which hold for a model solar atmosphere in radiative equilibrium with a grey coefficient of absorption, and showed how closely this prediction was obeyed by the Sun itself. In his Smith's Prize Essay he was the first to treat the inverse problem of finding the temperature distribution from the observed darkening to the limb, and gave a solution, commonly ascribed to R. Lundblad, who independently and slightly subsequently had reached the same result in a paper in the *Astrophysical Journal*. In this same Essay Milne also discussed the effect of simultaneous scattering and absorption in a stellar atmosphere, and gave the first solution of the Milne–Eddington equation of transfer, more usually applied to the formation of absorption lines. These and a great variety of related investigations were lucidly described in his *Handbuch* article " Thermodynamics of the Stars " —a work which is still standard and has formed the starting-point of the more elaborate modern investigations of Hopf, Chandrasekhar and Kourganoff. Milne had been among the first to recognize the revolutionary consequences of Saha's theory of thermal ionization, and as described by Professor McCrea, Fowler and Milne together applied this theory in a quantitative fashion to fix the temperature scale of the stellar spectral sequence. Arising from this work the two authors became interested in unit mechanisms and the principle of detailed balancing, and in a beautiful paper in the *Philosophical Magazine* Milne used this method to derive Saha's equation and to discuss the absorption coefficient in the Balmer and Lyman continuous spectra. Almost simultaneously appeared related papers on radiation pressure and chromospheric equilibrium,