HUGH FRANK NEWALL was born on 1857 June 21 at Gateshead-on-Tyne. His father was Robert Stirling Newall, F.R.S., inventor and manufacturer of wire ropes, who constructed most of the first submarine cables and personally took part in the laying of them. His mother was a daughter of Hugh Lee Pattinson, F.R.S., who invented a process for desilverising lead. Mr. Pattinson had a $7\frac{1}{4}$-inch equatorial by Cooke of York—a large telescope in the days when a 15-inch was the largest refractor in existence. This may well have inspired Mr. Newall, who had wide scientific interests and had already made a series of drawings of the Sun, to seek for an opportunity to construct and mount a very large refractor. At the Exhibition of 1862 he saw and acquired two rough disks of crown and flint glass exhibited by Messrs. Chance of Birmingham; these were sent to Cooke's for figuring and were shown at the British Association meeting at Newcastle in 1865. It was not till 1871, however, that the dome and mounting were finished, and the 25-inch equatorial telescope of 29-foot focal length was erected in an observatory set up in the garden of Newall's home at Ferndene.

When Frank Newall left for Rugby School in 1872 the telescope which was to mean so much to him throughout his later life had just come into full being. But neither at school nor in his years (1876–1880) at Cambridge, where he graduated in Mathematics, did he show any leaning towards becoming an astronomer. His marriage in 1881 with Margaret Arnold, daughter of his old housemaster, was probably not unconnected with his going to Wellington College as an assistant master. Before he left Wellington in 1883 he had published his first paper on "Internal Reflexions in the Eye" (*Proc. R.S.*, Jan. 1883) in which his power of observation and keen interest in natural phenomena were both clearly evidenced. He and Mrs. Newall travelled abroad, staying for some time in Perugia, and meanwhile Newall published two more papers showing his interest in simple phenomena, observed under experimental control. The first was on "Colliding Water-jets" and the second on the "Formation of Vortex Rings by Drops falling into Liquids". This paper was written jointly with J. J. Thomson, Cavendish Professor of Experimental Physics at Cambridge University, who invited Newall to join him as Assistant and Demonstrator of Experimental Physics in succession to Richard Threlfall: his colleagues were Glazebrook, Napier Shaw, and Randell. Newall returned to Cambridge in 1881 October, to reside there for the rest of his life. The subjects of his next three papers still showed no sign of his future career; they were "Electricity Leaking through Badly Conducting Liquids" (with J. J. Thomson), "Peculiarities of Iron and Steel at Bright Red Heat", and "Recalescence of Steel".

Then came a series of events which entirely altered his life. His father had always intended that his great telescope should be transported to a southern climate, but various offers which he had made from time to time for its use under more favourable conditions than obtained at Gateshead had failed for one reason or another. Amongst these offers was one in 1876 for use at a proposed Physical Observatory, "for application to the development of Physical Astronomy", and another in 1879, when Gill was going out to succeed Stone as His Majesty's Astronomer at the Cape, for a seven years loan to the Cape Observatory. This latter offer was rejected on the ground that the expense involved, £3000, was unduly high for the use of a borrowed telescope. Finally on 1889 March 4, a month before his death, Mr. R. S. Newall wrote to the Vice-Chancellor of the University of Cambridge offering the telescope to the University. He said that the telescope had done "no systematic work in its present position owing to unfavourable atmospheric conditions and other reasons"; he further expressed a wish to place it where it would work under capable direction and hoped that the possession of an instrument especially adapted to the study of Stellar Physics might give impetus to the development of the subject. Subsequent history shows to what an extent these hopes were realised.

The University appointed a Syndicate to consider the offer, the members being Adams, Routh, Glaisher, Liveing, Darwin and Thomson. A favourable report on the telescope's qualities from Christie, Common and Graham (first assistant observer at the University Observatory) led the Syndicate to recommend the University to accept the offer and to call the telescope "The Newall Telescope". But difficulties of a financial nature arose in the matter of the expenses involved in the move and in the staffing of the observatory. Newall, anxious to see his father's telescope put to full use, offered the syndicate £300 towards the initial expenses and in addition his services as observer for five years without stipend, if he could find a site for a house near to the observatory, or, if he could get no house nearby, a sum of £200 a year towards the annual expenses. The Syndicate recommended the University to accept this offer and to appoint Newall as observer "conditionally on his providing himself with a residence within" 500 yards of the observatory. The University accepted the recommendation and thus came into existence a house, "Madingley Rise", well known to many astronomers from all over the world for the following fifty years. Here the Newalls extended gracious hospitality to a wide circle of friends, and one might meet astronomers from overseas—Backlund, Campbell, Gill, Hale, or Michelson to mention only a few—or British scientists—Dyson, Fowler, Huggins, Parsons, Turner—or musicians who kept alive the link between Mrs. Newall and Joachim. Madingley Rise became a centre of culture in Cambridge, acquiring in later years an old-world accent; symbolical of this and of Newall's conservative outlook on life was his carriage and pair driven by the faithful Arthur and surviving long after the incoming of the motor-car. On his death Newall bequeathed his house to Trinity College.

Newall resigned his demonstratorship in 1890 and was largely occupied for the next two years in superintending the move and re-erection of the telescope and dome. It is not without interest that the erection of the new telescope led to gas being laid on to the main University Observatory. Newall became a Fellow of the Society on 1891 June 12 and published his first paper in the *Monthly Notices* in 1892 May, a note on the "Comparison of the Magnitudes of Nova Aurigæ and neighbouring Stars" during 1892 March and April. His first report as Newall observer was made to the University in 1892 June and to the Society in the Council Report for 1893. Pending the arrival of new clockwork from Grubb's to improve the driving of the telescope Newall made observations on planets, Barnard's satellite of Jupiter and Swift's comet 1892 *a*. But he had not forgotten his father's wishes that the telescope should be devoted to physical astronomy, wishes entirely in accord with his training and outlook as an experimental physicist. His second paper in the *Monthly Notices* was on "A Diagram for use in adjusting a Diffraction Grating Spectroscope"; with the aid of two objective prisms lent by Norman Lockyer he began obtaining bright-star spectra, while he set to work on the task of designing a spectrograph for use with the telescope.

Much preliminary work had to be done which found expression in a "Note on Stellar Photographs secured with a Visual Telescope"; the effects of chromatic aberration, spherical aberration, varying aperture and of the use of different photographic plates were studied, and he became convinced of the paramount need for a correcting lens to meet the troubles due to chromatic aberration of the object-glass of the telescope. Ultimately he decided to use a single concavo-convex Cooke lens which brought the focus of the telescope to a point 18 inches inside the tube. This has a number of advantages which Newall was quick to seize. The attachment of the spectroscope to the telescope was strengthened, the whole spectroscope and the correcting lens slid in and out for focusing, the convergence of the cone of rays from the object-glass was reduced and a gain in convenience of handling the instrument was found in improved clearance from the observing platform. On the other hand, with the slit inside the telescope devices had to be designed for seeing the image of the star on the slit and for getting the comparison spectra on the plate. Huggins's plan of a reflecting slit plate of speculum metal was adopted, and much ingenuity was shown in the subsidiary optical train required to overcome the inaccessibility of the slit.

Newall did not take long to decide that objective-prisms were not suitable for use with a telescope of so long a focus as 29 feet, and experiments on different prism arrangements led to a further decision against a direct vision type of spectrograph owing to the loss of light in the dense flint prism. Being anxious to make use of the still exceptionally large light-gathering power of the telescope for work on fainter stars, he adopted the plan of a single-prism slit spectrograph. The cost of this instrument was borne by a gift received from Miss Bruce's Grant in Aid of Astronomical Research. The offer came from E. C. Pickering of Harvard to Adams for the purchase of an instrument for the Cambridge Observatory. Ultimately the gift was made through Ball, who had meanwhile succeeded as Director of the University Observatory on the death of Adams. In recognition of the American source of the money required for the Bruce spectroscope, as Newall called it, the optical parts, save a telephoto lens made by Dallmeyer, came from Brashear's of Allegheny. The mechanical parts were made by the Cambridge Scientific Instrument Company. (The spectrograph was described in *Monthly Notices*, **56**, 98, 1896, and the paper was repeated in the *Astrophysical Journal* as No. XVII in a series of articles on "The Modern Spectroscope".)

The chief activity of Newall during the years 1893–6 had been in connection with the design and testing of the new spectrograph. But he wrote in addition a paper on the spectrum of Argon (*Ap. J.*, **1**, 372, 1898) and a further note on the formation of photographic star-disks; also he carried out such visual observations as micrometer measures of Phobos during the opposition of Mars of 1894 and occultations of stars during the total lunar eclipse of 1895 March 10. In 1895 too he made an observation at Riffelberg which was to colour his views of solar physics over many years. Observing the Sun through a spectroscope he saw isolated islands of the C line of hydrogen displaced towards the red. Violent local downrushes of hydrogen on the Sun were seen, some of which persisted for many hours. For long this remained an isolated observation, though of recent years it has been confirmed by the work of McMath, Lyot and others. An echo of Newall's own observation and consequent speculations is to be heard in a paper published by the Royal Society in 1897 on "Luminosity attending Compression of certain rarefied Gases". Here he suggests that gradual streaming-in of rarefied gases might give a pressure-glow which could account for the maintenance of luminosity and persistence of outline of the gaseous nebulæ. The speculation is to be judged in the light of our ignorance at the time of the nature of the nebulæ and of the sources of luminosity in gases. It gave evidence of a mind alert to apply new results to old problems.

Newall, who had commenced forty-three years continuous service on the Society's Council in 1893, was elected Secretary in 1897 *; in which year he offered to serve a further term of five years as Newall Observer without stipend. In announcing his generous offer the Observatory Syndicate expressed the view that the provision of a stipend for the Newall Observer was an urgent claim on the funds of the University. In 1896 and 1897 Newall commenced a study of stellar velocities in the line of sight only to run into serious difficulties through systematic trouble due to deflection of the collimator. The work was suspended while Newall was away in India observing a total solar eclipse and was renewed in 1899 July with higher dispersion obtained with the aid of a 4-prism spectrograph which had replaced the Bruce spectrograph. An early result was the discovery that *Capella* was a spectroscopic binary, a discovery made independently by Campbell at the Lick Observatory. Full details of Newall's observations were given in the *Monthly Notices* in 1900 March; they gave a period of 104 days and also estimates of the mass and absolute brightness of *Capella*.

Fresh calls upon Newall at this period came in connection with instrumental developments in the University Observatory; he served with Stokes and Ball on a committee on the New Photographic (Sheepshanks) Telescope, taking his share in the discussions on the design of the instrument and its building, and he also shared some of the diffi-

* He wrote the note on Stellar Spectroscopy for the Council's annual report every year, save one year of his Presidency, from 1898 to 1920.

culties that faced his nephew, Bryan Cookson, in the design of the Cookson Floating Zenith Telescope. Preparations for solar eclipse expeditions, the actual expeditions themselves and the preparations of subsequent reports all took their share of his time and energy. At this juncture we may turn aside from the narrative of his life to discuss his eclipse activities.

The first solar eclipse that Newall observed was at Pulgaon, India, on 1898 January 22. Mrs. Newall, as always, accompanied him on the expedition and shared in the observations. Captain E. H. Hills, R.E., was the other member of the party and Captain G. P. Lenox-Conyngham, R.E., was officer in charge of the eclipse camp. A 4-prism spectrograph with two slits mounted on a polar heliostat was used for an examination of the rotation of the corona, and a study of flash and coronal spectra on the two limbs. No trace of the coronal spectrum was found, but flash spectra were obtained. An objective-grating telescope was used for visual observation of the green coronal ring. No fine radial coronal structure was observed, but broad patches of light, coinciding roughly with marked broad extensions of the photographed corona and not with prominences. First attempts were made with Nicol prisms and attached Savart plates to study visually the polarization of the corona and the surrounding sky. Fundamentally these were the subjects of Newall's observations during most of his subsequent eclipse expeditions.

His second expedition was with Turner to Bouzareah, in the grounds of the Algiers Observatory for the eclipse of 1900 May 28. The 4-prism spectrograph was used with a polar heliostat for flash and coronal spectra at both contacts, this time with one slit instead of two. Twelve plates were used and changes in the flash spectrum noted from plate to plate. The absence of Fraunhofer lines in the coronal spectrum was noted as surprising, as strong bands were found over the corona photographed through a Nicol prism and Savart plate set for extinction of the sky bands. Mrs. Newall observed, using small Savart polariscopes, the polarization of the sky in points symmetrically disposed round the Sun.

The next eclipse observed by the Newalls was on 1901 May 17–18 at Sawah Lorento in Sumatra. This eclipse was marred by the presence of thick cirrus clouds which spoilt the high dispersion spectra of chromosphere and corona. Photographs taken through a double tube camera, with a Nicol prism and Savart plate in front of one lens, showed marked polarization of the corona. Good plates were secured with an objective-grating camera, while visual observations of the coronal ring again showed no fine structure.

Better weather awaited Newall at the eclipse of 1905 August 30 which he observed at Guelma, Algeria. Visual observations of the plane of polarization of the Earth's atmosphere were made early in the eclipse to help in setting the polarisers used in the photographic work for extinction of the sky bands. It was noted that the atmosphere diffused as much polarized light as the corona at 1·5 diameters from the limb. Photographs taken through a Nicol prism and Savart plate showed atmospheric polarization in step with coronal polarization in two quadrants, and out of step in the other two quadrants, confirming the visual observations that the sky polarization was horizontal and the coronal polarization radial. Polarization could be traced as close in as 1′ from the limb. No Fraunhofer lines were found in the polarized spectra secured with a single-prism spectrograph in front of which was placed a large double-image prism. It was noted from a comparison of direct photographs with polarized images taken through Nicol and Savart cameras that polarization varied through the corona, being weak in the arches and strong in the streamers. Abney standard squares were used on many of the coronal plates, as also in the 1901 eclipse.

Of the four eclipses observed between 1898 and 1905 only preliminary reports were ever published. Owing to pressure of other commitments Newall never found the opportunity to settle down to a final detailed study of his material. A recent study by

Brück (*M.N.*, **104**, 33, 1944) of the brightness distribution in a direct photograph of the corona secured at Guelma (in a paper read to the Society at the meeting at which Newall's death was announced), points to the existence of important eclipse material of Newall's still well worth studying.

With his intense eclipse activities in the years 1898–1901 it would not have been possible for much other work to be produced, but we may note a thorough study of the scale for a new Zeiss comparator for measuring spectra, a study of an unconfirmed variable radial velocity for α Persei, the fluctuations being ascribed by Newall to temperature changes, a set of spectrograms secured of Nova Persei 1901 and the addition of an annex on the north side of the dome to give opportunities for students to take part in the work of the observatory. In 1902 a gas engine and dynamo were installed in this annex for use in spectroscopic observations.

Newall continued to work on line-of-sight velocities in co-operation with Frost of Yerkes and directors of other observatories, but this work, as we shall see, got gradually crowded out by fresh developments in his activities. He had been elected a Fellow of the Royal Society in 1902, and on 1904 February 11 he was appointed to the Honorary Office of Assistant Director of the University Observatory. A full description of the 4-prism spectrograph used in the various eclipse expeditions and of the Newall telescope was given by Newall (*M.N.*, **65**, 636, 1908) following an important paper on the general design of spectrographs to be attached to equatorials of large aperture. This had special application to the effect of tremor disks and dealt with the diffraction method of estimating slit-width and the conditions for the economic use of light. In the struggle between the need for a wider slit for more light and the necessary larger train of prisms with more consequent loss of light, Newall sums up in favour of a narrow slit and shorter prism train. He also expresses a view in favour of a reflector with diffraction-grating spectrograph as suffering less from general atmospheric troubles than a refractor and prism spectrograph.

In 1905 a new chapter in the history of astrophysics at Cambridge opened up with the munificent bequest of £5000 from Frank McClean for the improvement of the instrumental equipment of the Newall Observatory. A special McClean Fund was founded, the observer in charge of the Newall Observatory to make, subject to the approval of the Observatory Syndicate, applications for grants for specific purposes. Newall began a special study of the suitability of atmospheric conditions for solar spectroscopic work. The Newall telescope was temporarily adjusted for solar observations, a grating being mounted instead of prisms, and a 4-inch finder being used with a projection screen to assist in the orientation of the telescope. Later the object-glass was dismounted for horizontal projection of a solar beam from a cœlostat and sunspot spectra were studied with a Cooke spectrograph formerly used by Piazzi Smyth and put at the disposal of the observatory by the Royal Society. A new observing hut was erected on the south side of the Newall dome for the cœlostat.

The growing development for solar work, the accumulation of observational material and the need to supplement the telescope by the laboratory led the Observatory Syndicate at this stage to propose the appointment of an assistant of University standing. Hitherto Newall had worked single-handed save for one laboratory assistant (A. W. Goatcher 1892–1901; H. J. Bellamy 1901–5; W. H. Manning after 1905; L. J. Stanley joined for solar work in 1906). Now an assistant in Astrophysics, whose University stipend was augmented by Newall, was appointed, the first holder of the post being Bryan Cookson.

The trials of conditions for solar spectroscopy were decisively favourable and from the McClean bequest the expense of a new installation was found. A cœlostat was set up in the hut south of the dome, a 12-inch lens of 60-foot focal length sent a beam horizontally across the dome to a Littrow grating spectrograph mounted in the north annex. Work was commenced on laboratory spectra under varying physical conditions and on bands in the solar spectrum, notably the cyanogen band at 3883 and the bands in the red. Foreign students began to appear at the observatory, among others R. Rossi from Italy and Hubrecht from Holland. The latter worked on solar rotation, a subject in which Newall had long been interested. The Presidency of the Royal Astronomical Society 1907–9 and a Fellowship at Trinity College in 1909 bore witness to the growing appreciation of the work that Newall was doing for Astrophysics.

Next, on 1908 November 12, came an offer from the Royal Society, made on the suggestion of Sir William Huggins, that the telescopes and spectroscopes provided for his use under an endowment at the disposal of the Society should be presented as a gift towards the astrophysical equipment of the observatory. Huggins had found it necessary to discontinue active astronomical observations. This offer was accepted by the University, money was found (partly from anonymous sources) for the erection of a dome to house the telescopes with which Huggins had carried out his pioneer researches; in addition a Huggins observer's room, a computing room and library, and a small room for the head of the Astrophysical Department were constructed. The new building was called the Astrophysical Building and it had the Huggins dome placed at one end of it. Huggins did not live to see the transfer of his instruments completed, but he and later Lady Huggins made valuable additional gifts of instruments and photographs. Another valuable gift following on the Royal Society's came from Major E. H. Hills for the use of Newall and his successors; this included a 4-prism quartz spectrograph with 5-inch quartz objectives, a heliostat with 12-inch mirror by Common and other prisms, lenses and accessories.

At this stage the University felt the need for further recognition of Newall's status. A Chair in Astrophysics without stipend was established, and Newall was elected as Professor of Astrophysics on 1909 June 15. In that year he founded the Observatory Club for meetings of staff and students, and in 1910 a small book on *The Spectroscope and its Work* was published (S.P.C.K.).

From now on Newall retired gradually from active night work, but he continued to observe the Sun with the McClean equipment. Fresh responsibilities and administrative cares were coming his way, for on 1911 October 23 a letter was received by the Vice-Chancellor of the University from the President of the Board of Education conveying a recommendation made by a departmental committee that the Solar Physics Observatory, which had to be moved from South Kensington, should be transferred to Cambridge. The members of the committee who made the recommendation were Sir Thomas Heath, Sir Frank Dyson and Sir Arthur Schuster; Sir Richard Glazebrook dissented from their view. The committee stated that "having regard to the advantage to the progress of Solar Physics which may be expected to accrue from the establishment and support by the University of a real school combining the study of Solar Physics and Astrophysics the Cambridge scheme is calculated to give the better results". One condition laid down was that the Professor of Astrophysics should be the Director of the Solar Physics Observatory, the previous Director, Sir Norman Lockyer, having retired. An annual grant in aid was paid to the University and an initial grant for building. The Astrophysical Building was enlarged by the addition of a laboratory, workshop, dark room, staff rooms and a house for a resident attendant. Separate buildings were added for the 3-foot Common reflector and the spectroheliograph. The new buildings for the staff and the laboratory were ready when the Solar Physics Observatory was taken over by the University on 1913 April 1. One more gift has to be recorded—a gift of £500 from St. John's College as a contribution to the equipment of the Solar Physics Observatory. The Chair of Astrophysics was partially endowed by an anonymous donor, the offer to become effective on the termination of Newall's tenure of the Chair. The donor made the endowment over to the University in the summer of 1928, Newall retired in the following November.

To return to Newall's published work we may mention a note on the spectrum of the daylight comet 1910 *c*, and a note on bright lines in the spectrum of the Sun's limb at the partial eclipse of 1912 April 16–17. This flash spectrum of an upper stratum of the reversing layer suggested to Newall that valuable results might be obtained by an observer using instruments of high dispersive power just outside the belt of totality at an eclipse. A similar observation and suggestion were made independently at the same time by A. Fowler.

An expedition to observe the total eclipse of 1914 August 20–21 found the Newalls at Feodosia in the Crimea when the Great War broke out. The programme of observations was along the general lines of Newall's previous expeditions, but cloud prevented any successful observations from being made. He returned to Cambridge to find his observatory with a reduced staff and to be asked to assist in tackling certain war problems for the services. Pure scientific work was compelled to proceed slowly, but he published a preliminary note with F. E. Baxandall and C. P. Butler on the identification of the G band in the Sun with the hydrocarbon band at λ 4314; he also began with W. Moss a study of sunspot areas and life-histories and of zones of prominence activity, while he continued observations on sunspot spectra with the McClean instruments. Later he began, with the aid of his secretary, Mrs. Beech, a study of the frequency of occurrence of groups of sunspots in different solar latitudes. Irregular proper motions were examined in connection with Hale's work on vortical motion. Detailed differences were found with relation to motions in latitude and longitude between the northern and southern hemispheres and related to epochs of frequency maximum. This led to a note to the Society on the "Law of Rotation of the Sun", and later to a study of the different relative motions of pairs of spots in one hemisphere in successive sunspot cycles.

Other papers published were on Nova Geminorum, 1912; Nova Aquilæ, 1918; and Nova Cygni, 1920. His last published paper was with Carroll, Smart and Butler on an expedition to Aal in the Hallingdal, Norway, for the eclipse of 1927 June 29. Bad weather again prevented any observations. The programme of observations showed two developments from the earlier programmes in the use of spectrophotometry for flash and coronal spectra and interferometric measurements for accurate coronal wavelengths and line-widths.

The following year Newall resigned his Chair and his post as Director of the Solar Physics Observatory. His years of retirement were saddened by the death in 1930 of Mrs. Newall, his companion for nearly fifty years. She did not live to attend later in the year the presentation to the University of his portrait by Fiddes Watt, painted at the request of numerous friends and admirers. The portrait is now in the Director's room at the Solar Physics Observatory. Newall married again in 1931 Dame Bertha Surtees Philpotts, sometime mistress of Girton College and a very close friend of his first wife and himself. But she was already stricken with a serious illness when they married and she died in the following year. Newall lived on quietly at Madingley Rise for twelve more years, keeping touch with his circle of friends both in the University and outside, especially with overseas astronomers as opportunity offered for them to visit Cambridge.

There is another aspect of his astronomical work which must be mentioned here, that of international co-operation. He was appointed to represent the Royal Society in 1905 at the Oxford Conference of the International Union for Co-operation in Solar Research: there he was made chairman of a committee on the Investigation of the Spectra of Sunspots, and two years later at Meudon he brought forward a proposal for a committee on Solar Rotation, of which he was made a member. He was chairman of this committee at the Mount Wilson meeting of the Union in 1910, where he proposed that the Union should extend its scope to include the subject of stellar spectra; he was made a member of a committee on Stellar Classification resulting from the adoption of his proposal. At Bonn in 1913, a meeting which he was unable to attend owing to illness, he was further made a member of a committee for photographing features of the solar atmosphere and studying motions in the solar atmosphere other than rotation.