Solar Telescope at Oxford

THE new solar telescope of the University Observatory, Oxford, which was formally declared open by the Vice-Chancellor on June 11, is in its essence a vertical Cassegrain telescope of 12½ inches aperture and 73 feet focal length. It gives a solar image some eight inches in diameter, and unlike the original tower telescopes (the 60-ft. and the 150-ft. at Mount Wilson) the present instrument is wholly free from chromatic aberration. Further, since the image is formed on the optical axis, the telescope is free from the extra axial aberrations characteristic of horizontal solar reflecting telescopes. Light is fed into the vertical Cassegrain telescope by a 16-in. cœlostat, driven by a synchronous motor, and a secondary mirror of the same aperture. Both cœlostat and secondary mirror are provided with electrical slow motions which are controlled by a portable keyboard near the focal plane of the instrument; the same keyboard also carries controls for focusing the Cassegrain mirror.

The telescope is unique in that it is the only large solar telescope in which all the optical parts are made of fused silica. Since fused silica has a coefficient of expansion 1/20 that of ordinary glass, and 1/7 that of pyrex, it follows that the differential expansion produced by solar radiation, which tends to make the plane mirrors concave and so to produce an astigmatic image, will be almost wholly avoided in this instrument. The telescope, mounted in the east tower of the observatory on the same pier and under the same dome which housed the De la Rue reflector, was constructed by Sir Howard Grubb, Parsons and Co., of Newcastle, the blanks for the fused silica discs having been supplied by the Thermal Syndicate, Ltd.

On the optical axis of the telescope lies the slit of a large Littrow spectrograph. The spectrograph has two 60° and one 30° prisms of six inches square aperture (height 6 inches, length of face 9·7 inches), and a collimating-camera lens of six inches aperture and some 30 feet focal length. It gives a dispersion at λ4200 of 2·6 mm. per A., and a theoretical resolving power of more than 300,000. The optical parts, supplied by Adam Hilger, Ltd., and a large minimum deviation mount, supplied by C. F. Casella and Co., Ltd., are mounted at one end of a 40-ft. brick tunnel constructed in the basement of the observatory. The spectrograph, which still lacks the essential temperature control for the prisms, the slit end and plate holder mechanism, and a guiding disc, will be completed as funds permit.

In declaring this equipment open, the Vice-Chancellor referred to the chequered history of attempts to establish a permanent observatory in Oxford. No less than three unsuccessful attempts have been made, namely Bishop Fell's failure to persuade Wren to incorporate an observatory in Tom Tower, the establishment of a temporary observatory for Halley in 1704 in New College Lane, and finally the construction of an observatory by the Radcliffe Trustees in 1773, now regrettably, from the point of view of Oxford at least, departing for South Africa. The University Observatory was built by the University some sixty years ago, and the fact that the University has, during a period of exceptional financial stringency, set aside some £3,700 for the purchase of the present equipment may be regarded as evidence both that it desires the present observatory to be a permanent institution, and that it desires to see the study of observational astronomy actively prosecuted at Oxford. The Vice-Chancellor concluded his remarks by expressing the warm hope that some donor, interested in the study of astronomy, would find it possible to provide the relatively small sum needed to complete this equipment.

After the Vice-Chancellor's declaration, and following a period when the instruments were inspected by the assembled company of astronomers, Oxford men of science and other members of the University, the proceedings were concluded by an address by Sir Arthur Eddington on "The Physics of the Sun". Sir Arthur pointed out that the sun may be regarded as composed of three parts, an airy appendage where the atoms are supported by radiation pressure, a middle region where the absorption lines are formed and which is therefore readily accessible for observation with the equipment which had just been inspected, and finally the observationally inaccessible deep-lying interior. While there is a temptation to separate what is observable from what can only be inferred, the creation of such artificial divisions is likely to lead to 'frontier incidents'. The sun is a unit and must be treated as such. Sir Arthur then went on to point out how, in spite of its inaccessibility, it is possible to infer much about the physical conditions in the deep interior, and how such information has been confirmed in a striking way by developments in nuclear physics. In moving a vote of thanks to the lecturer, Prof. E. A. Milne, in a peculiarly happy vein, referred to the many distinguished astronomers and solar physicists who gathered to witness the ceremony and to hear Sir Arthur's masterly address.

H. H. P.

Interpretation of Spectra

PROF. HENRY NORRIS RUSSELL delivered the George Darwin Lecture to the Royal Astronomical Society at the meeting of the Society on June 14, taking as his subject "The Analysis of Spectra and its Application to Astronomy". Prof. Russell explained that he did not refer to the analysis of spectra in the sense of the analysis of the elements present or absent in a mixture, but to the analysis of the spectrum of each single element. The history of this analysis goes back to 1883, when it was discovered that the various doublets in the spectrum of sodium possessed the same separation when expressed in wave numbers: Prof. Russell followed the development of this subject down to its rationalisation by Bohr and the introduction of the notion of states of energy which the atom may possess, the frequencies of the spectral lines being given by the familiar quantum relation $h\nu = E_1 - E_2$.

Comparatively recently, Hund has given a theory of the way in which the energy states of the atom are built up from the energies of the various electrons in the atom, and there is now a corpus of complicated but definite rules which govern the way in which levels are built up and the restrictions on possible electron jumps, jumps between 'odd' and 'odd' terms, for example, being forbidden. We can now fully understand the structure of even a complicated spectrum such as that of iron.

Turning to the practice of the analysis of spectra, Prof. Russell said that, before one could analyse a spectrum, one needed a list of lines with well-determined wave-lengths, the intensities of the lines, their temperature class (along the lines developed by King at Mount Wilson) and the Zeeman patterns. All the easy spectra have now been unravelled, but a few complex spectra remain to be analysed. Prof. Russell showed a slide exhibiting the present state of completeness of the analysis of the spectra of all the elements. Amongst those which are least analysed are the spectra of gadolinium, terbium, dysprosium, holmium, erbium, thorium, and uranium, while among the lighter elements the spectra of phosphorus, sulphur and chromium are not well analysed.

The astrophysical applications of the newer spectrum analysis were numerous. Saha's relation between the numbers of neutral and ionised atoms present in equilibrium at a given temperature and pressure had given the key to the general interpretation of the stellar spectral sequence. Identifications of lines are made much more reliable when reference is made to the intensity to be expected from the line's place in a multiplet and to the excitation potential of the atom in the state which absorbs the line. Identifications in the far infra-red spectra are particularly assisted by spectrum analysis, as very accurate wave-lengths are not to be obtained from laboratory measurement: a more accurate separation can sometimes be obtained from a corresponding separation in, say, the green, where good wave-lengths are obtainable. Again, the presence or absence of lines in the solar spectrum receives an explanation based on spectrum analysis. The non-metals do not show strongly, because the lines arising from atomic states with low excitation potentials lie in inaccessible regions of the spectrum. The great majority of apparent variations in abundance between the earth's crust and the solar disc is explained by the excitation potentials of the lines that are available. Only phosphorus, bismuth and radium are truly absent in the sun. Passing on to quantitative analysis, the theory of R. H. Fowler and Milne explained the major features of the spectral sequence, the apparent differences between one spectrum and another being due to differences in surface temperature and surface gravity.

Prof. Russell went on to say that while we recognise that a strong absorption line indicates many absorbing atoms and a weak line few, the detailed physical analysis is difficult. Dr. W. S. Adams and Prof. Russell had calibrated Rowland's scale of intensities—an arbitrary scale—by comparing Rowland's estimates of relative intensities within a large number of multiplets with theoretical intensities, and had applied this to the analysis of a number of stellar spectra. They discovered a departure from thermodynamical equilibrium; but recent work by Struve has thrown doubt on this method of calibration and the departure from thermodynamical equilibrium must now be regarded with caution. Prof. Russell concluded the lecture by referring briefly to bright line spectra and to the spectra of the planets.

Association of Teachers in Technical Institutions

AT the twenty-sixth Annual Conference of the Association of Teachers in Technical Institutions, which was held at Bournemouth during Whitsuntide, Mr. D. W. Lloyd (Old Trafford Technical Institute, Stretford) was installed as president for 1935–36 by the retiring president, Mr. H. J. Cull (Central Technical College, Birmingham).

In his presidential address, Mr. Lloyd said that during the past twenty-five years two dominant motives have been apparent—the desire to preserve and extend liberty of thought and speech and the desire to mitigate human toil. The first is in the realm of social and political life; the second in the sphere of science and industry. Both, however, have produced effects which are world-wide and touch the sphere of education at every point. To the technical teacher, said Mr. Lloyd, the tremendous changes in our industrial system due to technological development must have special significance. "Magic has entered our research laboratories, scientific advancement and the mechanisation of industry have tended to shorten hours of labour and increased the possibilities for leisure, yet, in our present stage of our development, we are faced with the chaos and misery of unemployment." Rationalisation, he continued, is one of the results of the increasing application of science to industry; but it has produced (by the replacement of as many employees as possible by the minimum number of machines) the paradox of a world of increasing production in which vast numbers are unable to secure the necessities of life. The machine, however, should not be arrested, since mechanical perfection increases human possibilities, and since the machine can "do the job better than its creator".

Long-range planning in industry and education, however, becomes essential. "The isolation of countries has disappeared . . . geographical barriers are non-existent except to those who think in ancient terms, international wireless communication has no limits unless hampered by those who fear the free movement of thought . . . new industrial contacts are possible; under control they can expand and make friendships. Education in its widest aspects can become an international force, and thus help to replace the narrow spirit of nationalism by the wider appeal of internationalism."

Mr. Lloyd specially stressed the need for liberty of thought. The unrest of the present world, he said, has produced intolerance and the stifling of criticism: in certain cases it has led to the establishment of dictatorial power which must have a reactionary effect on educational progress. Civilisation cannot advance without criticism, and the subjection of the individual will by inhibitions from the outside leads to stagnation and putrefaction. Propositions which may seem obscene, heretical and revolutionary will