not insist that that observation is absolutely conclusive. It is certainly strong evidence. But the subject is difficult, and one that has given rise to some difference of opinion among physicists. At any rate this property distinguishes argon very sharply from all the ordinary gases.

One question which occurred to us at the earliest stage of the inquiry, as soon as we knew that the density was not very different from 21, was the question of whether, possibly, argon could be a more condensed form of nitrogen, denoted chemically by the symbol N_3. There seem to be several difficulties in the way of this supposition. Would such a constitution be consistent with the ratio of specific heats (1·65)? That seems extremely doubtful. Another question is, Can the density be really as high as 21, the number required on the supposition of N_3? As to this matter, Prof. Ramsay has repeated his measurements of density, and he finds that he cannot get even so high as 20. To suppose that the density of argon is really 21, and that it appears to be 20 in consequence of nitrogen still mixed with it, would be to suppose a contamination with nitrogen out of all proportion to what is probable. It would mean some 14 per cent. of nitrogen, whereas it seems that from $1\frac{1}{2}$ to 2 per cent. is easily enough detected by the spectroscope. Another question that may be asked is, Would N_3 require so much cooling to condense it as argon requires?

There is one matter on which I would like to say a word—the question as to what N_3 would be like if we had it? There seems to be a great discrepancy of opinions. Some high authorities, among whom must be included, I see, the celebrated Mendeléef, consider that N_3 would be an exceptionally stable body; but most of the chemists with whom I have consulted are of opinion that N_3 would be explosive, or, at any rate, absolutely unstable. That is a question which may be left for the future to decide. We must not attempt to put these matters too positively. The balance of evidence still seems to be against the supposition that argon is N_3, but for my part I do not wish to dogmatise.

A few weeks ago we had an eloquent lecture from Prof. Rücker on the life and work of the illustrious Helmholtz. It will be known to many that during the last few months of his life Helmholtz lay prostrate in a semi-paralysed condition, forgetful of many things, but still retaining a keen interest in science. Some little while after his death we had a letter from his widow, in which she described how interested he had been in our preliminary announcement at Oxford upon this subject, and how he desired the account of it to be read to him over again. He added the remark, "I always thought that there must be something more in the atmosphere."

A SPECTROSCOPIC PROOF OF THE METEORIC CONSTITUTION OF SATURN'S RINGS.[1]

THE hypothesis that the rings of Saturn are composed of an immense multitude of comparatively small bodies, revolving around Saturn in circular orbits, has been firmly established since the publication of Maxwell's classical paper in 1859. The grounds on which the hypothesis is based are too well known to require special mention. All the observed phenomena of the rings are naturally and completely explained by it, and mathematical investigation shows that a solid or fluid ring could not exist under the circumstances in which the actual ring is placed.

The spectroscopic proof which Prof. Keeler has recently obtained of the meteoric constitution of the ring, is of interest because it is the first *direct* proof of the correctness of the accepted hypothesis, and because it illustrates in a very beautiful manner the fruitfulness of Doppler's principle, and the value of the spectroscope as an instrument for the measurement of celestial motions.

Since the relative velocities of different parts of the ring would be essentially different under the two hypotheses of rigid structure and meteoric constitution, it is possible to distinguish between these hypotheses by measuring the motion of different parts of the ring in the line of sight. The only difficulty is to find a method so delicate that the very small differences of velocity in question may not be masked by instrumental errors. Success in visual observations of the spectrum is hardly to be expected.

[1] Abridged from a paper, by Prof. James E. Keeler, in the *Astrophysical Journal* for May.

After a number of attempts, Prof. Keeler obtained two fine photographs of the lower spectrum of Saturn on April 9 and 10 of the present year. The exposure in each case was two hours, and the image of the planet was kept very accurately central on the slit-plate. After the exposure the spectrum of the Moon was photographed on each side of the spectrum of Saturn, and nearly in contact with it. Each part of the lunar spectrum has a width of about one millimetre, which is also nearly the extreme width of the planetary spectrum. On both sides of the spectrum of the ball of the planet are the narrow spectra of the ansæ of the ring. The length of the spectrum from *b* to D is 23 millimetres.

These photographs not only show very clearly the relative displacement of the lines in the spectrum of the ring, due to the opposite motions of the ansæ, but exhibit another peculiarity, which is of special importance in connection with the subject of the present paper. The planetary lines are strongly inclined, in consequence of the rotation of the ball, but the lines in the spectra of the ansæ do not follow the direction of the lines in the central spectrum; they are nearly parallel to the lines of the

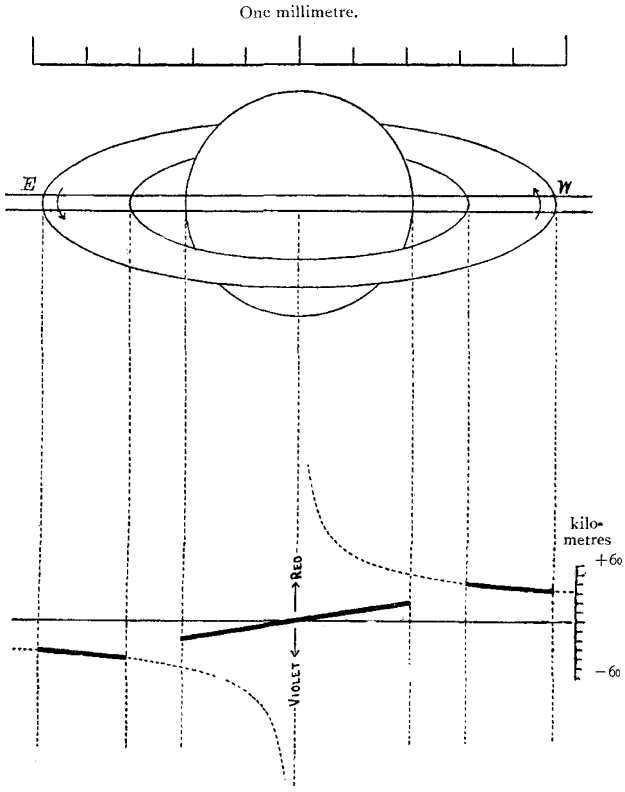

FIG. 1.

comparison spectrum, and, in fact, as compared with the lines of the ball, have a slight tendency to incline in the opposite direction. Hence the outer ends of these lines are less displaced than the inner ends. Now it is evident that if the ring rotated as a whole, the velocity of the outer edge would exceed that of the inner edge, and the lines of the ansæ would be inclined in the same direction as those of the ball of the planet. If, on the other hand, the ring is an aggregation of satellites revolving around Saturn, the velocity would be greatest at the inner edge, and the inclination of lines in the spectra of the ansæ would be reversed. The photographs are therefore a direct proof of the approximate correctness of the latter supposition.

It is interesting to determine the form of a line in the spectrum of Saturn when the slit is in the major axis of the ring, on the assumption that the planet rotates as a solid body, and that the ring is a swarm of particles revolving in circular orbits according to Kepler's third law. At present the motion of the system as a whole is neglected. The upper part of Fig. 1 represents the image of Saturn on the slit of the spectroscope (the scale

above it applies to the instrument used at Allegheny), and the narrow horizontal line in the lower part of the figure represents an undisplaced line in the spectrum, or solar line.

By Doppler's principle, the displacement of any point on this line is proportional to the velocity in the line of sight. The inclination of the planetary line to the solar line can be expressed by a simple formula. It is also possible to determine the form of a line in the spectrum of the ring, regarded as a collection of satellites, by the application of Kepler's third law. With the computed motions of different parts of the system, the dotted curves in the figure were plotted. For the ordinates, however, twice the calculated values were taken, since the displacement of a line, due to motion in the line of sight, is doubled in the case of a body which shines by reflected and not by inherent light, provided (as in this case) the Sun and the Earth are in sensibly the same direction from the body. The planetary line is drawn to the same scale, and the heavy lines in the figure represent accurately the aspect of a line in the spectrum of Saturn, with the slit in the axis of the ring, as photographed with a spectroscope having about three times the dispersion of the instrument used by Prof. Keeler.

The width of slit used is also represented in the figure.

If the whole system has a motion in the line of sight, the lines in the figure will be displaced towards the top or the bottom, as the case may be, but their relative positions will not be altered.

It is evident that in making a photograph of this kind the image must be kept very accurately in the same position on the slit-plate, as otherwise the form of the lines shown in the figure would be lost by the superposition of points having different velocities. The second plate was made with special care, and as the air was steadier than on the first occasion, the definition is on the whole somewhat better than that of plate 1, although the difference is not great. On both plates the aspect of the spectrum is closely in accordance with that indicated by theory, and represented in the figure. The planetary lines are inclined from 3° to 4°, and the lines in the spectra of the ansæ have the appearance already described.

If the ring revolved as a whole, the displacement of lines in its spectrum would follow the same law as for a rotating sphere; that is, the lines would be straight and inclined, their direction passing through the origin. If the ring rotated in the period of its mean radius, a glance at the figure shows that the lines would practically be continuations of the planetary lines. Such an aspect of the lines as this would be recognisable on the photographs at a glance.

It will be seen from the foregoing considerations that the photographs prove not only that the velocity of the inner edge of Saturn's ring exceeds the velocity of the outer edge, but that, within the limits of error of the method, the relative velocities at different parts are such as to satisfy Kepler's third law.

Besides (1) the proof of the meteoric constitution of the rings, explained above, each line of the photographs gives (2) the period of rotation of the planet, (3) the mean period of the rings, (4) the motion of the whole system in the line of sight. Prof. Keeler has measured a number of lines on each plate, and compared the results with the computed values of the corresponding quantities.

The results for (2) and (3) from both photographs are:

(2) Velocity of limb = $10{\cdot}3 \pm 0{\cdot}4$ kilometres,
(3) Mean velocity of ring = $18{\cdot}0 \pm 0{\cdot}3$ kilometres;

the computed values being 10·29 and 18·78 kilometres respectively.

Prof. Keeler has not yet determined from his photographs the motion of the whole system in the line of sight.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Mr. T. J. I. Bromwich, Scholar of St. John's College, is the Senior Wrangler of the year. There are thirty Wranglers, of whom St. John's furnishes ten, and Trinity six. One lady only is among the Wranglers, namely Miss N. A. L. Thring, of Newnham, who is placed twenty-third in the list.

The Tyson Medal for Astronomy is awarded to Mr. A. Y. G. Campbell, of Trinity.

Sir Edward Maunde Thompson, K.C.B., has been appointed the first Sandars Reader in Bibliography for the year 1895-6.

The Board of Managers of the Arnold Gerstenberg Studentship give notice that a Studentship on this Foundation will be offered for competition in 1896. The competition will be open to men and women who have obtained honours in Part I. or Part II. of the Natural Sciences Tripos, and whose first term of residence was not earlier than the Michaelmas term of 1890. The Studentship will be awarded to the writer of the best essay on one of the six subjects printed below. The essays must be sent before October 1, 1896, to Dr. Sidgwick, Newnham College, Cambridge. The Studentship will be of the value of nearly £90. It will be tenable for one year only, but subject to no conditions of tenure.

Subjects:—"A statement of the physicist's 'working conceptions' of Matter and Motion, together with a discussion of the philosophical questions to which they give rise." "A criticism of the diverse views that have prevailed from the time of Newton onwards as to the conceivability or otherwise of *Actio in distans*." "A critical examination of the doctrines of J. S. Mill concerning the ground of Induction and the Methods of Inductive Inquiry." "The limits and relations of mechanical and teleological explanations of natural phenomena." "A brief historical account and a critical examination of the views which make the phenomena of life dependent on the existence of a special vital principle." "Natural Selection considered as a special example of the general principle of Evolution."

WITH the view of encouraging University Extension students to take up systematic courses of study, the Local Examinations and Lectures Syndics have remodelled their scheme of Local Lectures Certificates, and have made several other changes of importance. The certificates are now arranged so as to form successive steps in a ladder of continuous work, beginning with the Terminal Certificate for one term's work passing through the Sessional Certificate for a year's work to the Vice-Chancellor's Certificate of Systematic Study for four years' work. There is also an Affiliation Certificate obtainable only at centres affiliated to the University. This certificate is accepted by the Education Department as qualifying a person to be recognised as an assistant teacher. This system is thus adapted to the needs of persons who merely desire a general acquaintance with the subjects taught, as well as to students who are anxious to make a more thorough study of them.

THE Technical Education Board of the London County Council will proceed in July next to award five of its valuable Senior County Scholarships. These scholarships, which are reserved as a rule for young men and women under nineteen years of age, are intended to enable promising and deserving students, who would otherwise be unable to afford the expense, to go through a three years' course at a University or at a Technical Institute of University rank. They are limited to those candidates whose parents are in receipt of not more than £400 a year. The scholarships not only give free tuition, but also a money payment of £60 during each of the years that the scholarship is tenable. They are primarily intended to encourage the pursuit of some branch of science, art, or technology, but they may also be awarded for the promotion of studies in modern languages or other branches of education. In making the award, the Board takes mainly into account the record of each candidate's past career and distinctions, and the evidence as to ability, industry, and good character which the candidate is able to supply. At the same time it reserves the right to apply any examination test that it may think fit. Full particulars may be obtained from the Secretary of the Board, at 13 Spring Gardens, S.W. Candidates should send in their names not later than June 29.

THE summer assembly of the National Home-Reading Union will be held at Leamington Spa, from Saturday, June 29, to Monday, July 8. Lectures will be given by Major Leonard Darwin, M.P., on "The National and International Advantages of the Study of Geography"; Sir Robert Ball, on "Comets"; Mr. H. Yule Oldham, on "The Discovery of America"; Mr. J. E. Marr on "The Geology of the District"; Mr. G. F. Scott Elliot, on "Interesting Problems in Botany, suggested by the Flora of the District." There will also be a conference on "The Wider Education," at which the chair will be taken by Dr. Hill, Master of Downing College, Cambridge. Addresses will be given by Miss Mondy, Dr. R. D. Roberts, a representative of the Oxford Delegacy for University Extension, Mr. T.