of posting the gentlemen's names as men who have not paid their subscription at the next meeting. The Council think, however, that it is scarcely necessary to do this, though they find it absolutely necessary to protect the Society against members who will not pay their dues, but who nevertheless use the JOURNALS. There seems to be a kind of epidemic disease in India with regard to subscriptions which are neglected to be paid; but we cannot have JOURNALS and books sent to Members when they do not pay for them. We therefore propose the following amendment to the Bye-Law which I give notice will be considered at the General Meeting in October.

"*Revised Bye-Law No. 27.*—If a subscription be not paid within one month of the due date, a notice shall be given to the member that he is in arrear. If the subscription be not paid within five months of the due date the member shall be informed by a notice that if the subscription be not paid within six months of the due date the JOURNALS and other publications of the Society shall not be sent to the member until payment of the overdue subscription. If the subscription be not paid within twelve months of the due date, the defaulter shall cease to be a member of the Society, unless otherwise ordered by the Council. The Council may, at any time, reinstate such member upon payment of all arrears."

This is the last meeting of the Session, and during the next three months there will be no meetings at all. The library and business part of the Society, however, does not close and those who want to get books and JOURNALS may do so.

The meeting was then adjourned to 29th October 1912.

Astronomical Optics.

BY C. V. RAMAN, M.A.

Astronomical Optics is a very extensive subject, and this is not very surprising considering the fact that our principal source of information in Astronomy—one might almost say our only source of information, if we exclude the stray pieces of meteoric matter that occasionally reach the Earth's surface,—is the radiation that reaches us from the objects in the sky. I have therefore to confine myself to a few branches of my subject in the present paper. In the paper which I read at the last meeting of the Society I discussed the phenomena of the "Diffraction of Light," and this leads me on to the application of the "Interference of Light" in Astronomical work. In fact the two subjects are very closely related to each other : it will be remembered that I explained Diffraction in my previous paper as the result of the interference of the effects of the very large number of light-sources into which we may conceive a light wave of limited extent to be split up.

Every reader of this JOURNAL can see for himself the bright and dark fringes due to the interference of two light sources with the simplest of apparatus. All that is required is an ordinary undeveloped photographic plate—quarter-plate size is very convenient. With a needle, two fine lines parallel and pretty close to each other should be ruled on the film, so that the light shows through the lines. On viewing the filament of an ordinary electric light or the edge of the flat flame of a paraffin lamp from a distance through the plate with the two lines close to the eye and parallel to the source of light, the fringes will be recognized at once. They are generally very sharp and clear, and the distances between the successive dark and bright bands are all equal. It will be found on trial that with the two slits wide apart the fringes are narrow and *vice versâ*. In fact the width of the fringes is inversely proportional to the distance between the two slits.

It is very instructive to compare the interference fringes due to two narrow slits held at a distance apart with the diffraction bands due to a single wide aperture. The differences are very marked. In the latter case, the central bright band is twice as broad as any of the bright bands on either side of it, and the central band is much brighter, in fact about 20 times as bright as the first order bands on each side of it. The result of this rapid falling off in intensity is that with a feeble source of light it is hardly possible to fix the position of the first dark bands on either side with much precision and in Astronomical work, the boiling of the image due to atmospheric disturbances renders this more difficult still. With interference fringes on the other hand we have equally spaced bands and the central band does not differ very appreciably in brightness from the bands on either side of it, provided that the width of each of the two slits is very narrow compared with their distance apart. The theory of the formation of these interference fringes has been sufficiently explained by me in my previous paper.

We now proceed to consider Michelson's application of interference fringes to the problem of the measurement of the angular diameters of planetary (or stellar) objects. It is well-known that micrometric measurements made by the best observers with the largest telescopes of objects like the satellites of Jupiter differ very largely (by 30 or 40 per cent.) amongst each other. The reason for this uncertainty is principally the broadening and diffusion of the image by diffraction and its disturbance by atmospheric causes. Hence the interest of Michelson's method, the theory of which is in its essentials fairly simple.

The simple apparatus which I described above comes in very useful here. If, instead of observing the narrow edge of the flame of a lamp through the pair of slits, the flame is viewed broadside on, the interference fringes will be found to be no longer visible. The explanation of this is that the different parts of the source produce each its own set of interference fringes. These are not "in register" so to say and their superposition results in the production of uniform illumination over the field. If the object-glass of a telescope had a cover put on with two narrow parallel slits cut in it at some distance apart from each other and a bright star were observed through the telescope, we would see in the field of view a narrow strip of light crossed by fine interference fringes. If, instead of a star, a planet were observed, the interference fringes would probably be no longer visible, the cause of their disappearance being the superposition of the interference fringes due to the different parts of the source. It is evident that the extent of the confusion depends on the angular diameter of the object viewed, and on the angular width of the interference fringes in the field. If the slits on the cover of the object-glass were gradually drawn apart, the fringes would gradually decrease in width and at a certain stage would become obliterated. The distance apart of the slits at which the fringes first cease to be visible gives us a measure of the size of the object viewed.

If, instead of being a disc of finite size, the object was a double star, the change in the visibility of the fringes as the distance between the slits is increased can be very readily calculated. If the angular separation of the double star (say θ) were equal to $\lambda/2a$ (λ being the wave-length and a the distance between the two slits), it is clear that the bright bands in the fringes due to one of the stars in the double would coincide with the dark bands of the other set, and the fringes would have just disappeared. When a the distance between the slits is further increased, so that $\theta = \lambda/a$ the fringes would re-appear with practically their full original intensity since the bright bands of one set coincide with the bright bands of the other set and *not* with the dark bands. In fact as a is gradually increased the fringes pass through alternate cycles of visibility and invisibility. With a disc of finite size instead of a double star as the object, the interference fringes do not regain their full degree of visibility when a is increased beyond the value at which they first disappeared. There should, however, be a very appreciable re-appearance.

This phenomenon of the restoration of the visibility of the fringes after their initial disappearance with a source of finite size is one of considerable interest, and I was at some pains to verify it experimentally with simple apparatus. In fact, I had no arrangement at my disposal by which the distance apart of the two slits could be gradually increased. A little consideration will show, however, that precisely a similar effect should be obtained by having the two slits at a constant distance apart and gradually increasing the size of the source. A single slit with adjustable jaws held against a window gives us a source whose size can be varied at will, and this is used instead of the paraffin lamp or the incandescent filament in the experiment previously described. As the width of the source is gradually increased, the initial disappearance, then the partial restoration, the second disappearance, etc., of the fringes can all be observed.

The value of the interference method is shown by the fact that working with slits only four inches apart on the object-glass of a telescope, Michelson obtained measurements of the diameter of the four principal satellites of Jupiter which were far less uncertain than the best measurements made by the micrometric method with the 40-inch glass at Yerkes.

I now proceed to consider another very important and interesting phenomenon, the Doppler effect. This refers to the change in the wave-length of radiations that is detected spectroscopically when the source and the observer are in motion relatively to each other along the line, joining them. The cause of this change in wave-length is not very difficult to understand. When the source and observer are in relative motion towards each other, each successive wave emitted by the source has a shorter distance to travel before it reaches the observer than it would otherwise have to do and therefore arrives sooner. The frequency of the disturbance as it passes the observer is therefore increased and the wave-length diminished. The spectrum lines are therefore shifted towards the violet. The reverse is true when the source is moving away from the observer in the line of sight. An interesting acoustic analogy is furnished by a whistling locomotive as it passes the observer standing by, or situated in a train moving in the opposite direction, a sudden flattening of the note being very appreciable, as the text-books say. Curiously enough I have no recollection of having noticed this phenomenon, probably I never paid any attention to it when on the rail-road.

Doppler's principle has had many and wide applications in astronomical and astrophysical work. Probably the most recent is the spectroscopic discovery of the rotation of Uranus. It is evident that if the planet is rotating, one limb of it should be moving towards the observer in the line of sight and the opposite limb away from the observer. If the slit of the spectroscope were set upon the image of the planet, the wave-length of the light from the two ends of the slit would be altered in opposite directions, and we would as the result have the lines crossing the spectrum at an *inclination* instead of perpendicularly. This was actually observed.

Double stars have been discovered by the Doppler effect, the components of which no telescope will show separated, and their time of revolution about their common centre of gravity determined. Such stars are called spectroscopic binaries. The first was discovered at the Harvard Observatory by Pickering. Observation of a number of spectra of this star taken at different times showed that the lines became double at stated intervals, an effect which could only be explained by assuming the source of light to consist of two bodies which alternately approached and receded, in other words two bodies rotating about their common centre of gravity. If we photograph the spectrum of a double star one of the components of which is a dark body, side by side with a comparison spectrum at various times, the spectrum lines are seen single, but then appear to change their position periodically. In other words the velocity of the bright component in the line of sight varies with its position in the orbit.

A large number of other applications of Doppler's principle could be mentioned, but undoubtedly the most important is the general investigation of the line of sight motions of the stars which coupled with the determination of proper motions (*i.e.*. motion at right angles to the line of sight) must in time furnish us with the key to the solution of that greatest problem of astronomy, the nature of motion of the multitude of suns which make up the Universe. As the fruit of investigations on this subject we have Kapetyn's two-stream theory of the Universe and so on. Professor Turner suggests in recent articles that these 'streams' are in reality the results of the gravitation of the Universe towards the centre of its systems.

It has been found possible to verify Doppler's principles experimentally in the case of light. The minimum velocity capable of modifying the wave-length to such a degree that the spectroscope will note the change is about half a mile per second. To obtain a source of light moving with such a tremendous velocity inside a laboratory, the only practicable plan appears to be to make use of multiple reflections from systems of mirrors mounted on the rims of rapidly revolving wheels. For the velocities used, the change of wave-length on reflexion from a normally moving mirror is identical with that due to a motion of a source with double its velocity, and the effect would evidently be augmented by multiple reflexion, the alternate sets of mirrors (mounted on the rim of moving wheels) being rotated in opposite directions. After such repeated reflexions the light is analysed by a powerful spectroscope which reveals the change of wave-length.

To Stark is due the brilliant discovery of a second method by which the Doppler effect may be demonstrated in the laboratory, and this was the employment of the Canal rays due to the electric discharge in a vacuum tube. These Canal rays are supposed to be positively charged gaseous particles which are shot down the tube with a tremendous velocity (a few hundreds of miles per second) and may be isolated by using a perforated Cathode through which the rays emerge into the space beyond. The light emitted by these particles in the direction of their motion when analysed by a spectroscope shows the Doppler effect in a remarkably striking way. As the exhaustion of the tube proceeds, a wing appears to split off from the spectrum lines and gradually moves towards the violet sides of the spectrum. The detached line is somewhat broad and diffuse on account of the differences in the velocities of the different particles. There is always a line present also in the original position, showing that some of the particles emitting the light do not share in the motion of the Cathode rays.

The Nebular Hypothesis.

By W. A. Lee.

The oldest views of the Universe represented the hosts of heaven as persons who had lived on Earth. This idea seems to have been widely held in Europe, in Asia, and by Negroes in Central Africa. Beliefs are gradually modified, they are subject to the universal law of evolution, and accordingly ideas as to the personality of celestial bodies gradually changed until in the Middle Ages it was generally believed that the planets