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APPLICATION OF THE INTERFERENCE METHOD TO THE STUDY OF NEBULAE

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The spectroscopic study of the sidereal universe has been made almost solely with a single form of apparatus, the prism spectroscope, the general form of which has remained unchanged. It is only in very exceptional cases that gratings have been employed. It is doubtless necessary to conclude that the prism spectroscope is the apparatus best adapted to that class of researches and although in the future it will probably continue to play a leading part, it is possible now to consider other methods which may be able to contribute, at least in certain cases, to the progress of our knowledge of stellar astronomy.

Interference methods in varied forms have shown their efficiency in the analysis of light both in laboratory researches and in the study of the sun. Our present work has for its single purpose to show that it is neither impossible nor difficult to apply these methods to certain problems of sidereal astronomy.

Interference methods may be employed with special convenience when the source of light under investigation emits a small number of monochromatic radiations; the case of continuous spectra having dark lines is less simple. We have applied our method to the study of nebulae whose spectra consist of a small number of bright lines.

The interference apparatus consists of a film of air between two plane-parallel surfaces covered with a thin coat of silver. The fringes produced are rings situated at infinity. The observing apparatus, visual or photographic, should give a sharp image of those rings. It is desirable that there should be no mixing of the radiations emitted by the different parts of the object, and consequently that the sharp image of the nebula should be formed in the same plane as that of the rings. The most simple manner of arriving at this result would be to place the interferential apparatus in front of the entire observing apparatus; but then we should be limited as to the diameter of the objective by the size of the silvered film; and further, the apparent diameter of the rings would be very large with respect to that of the nebula.

The following arrangement overcomes both these difficulties. The interference apparatus is placed at the end of the telescope, set upon the nebula for an eye focused for infinity and consequently forming an afocal system; on looking through this, if the eye is focused for infinity, it will see a sharp image of the nebula on which the interference rings will be projected. It is not possible to use more than a small surface of silver, hardly larger than that of the ocular ring; the apparent diameter of the rings is not changed, while that of the nebula is multiplied by the enlargement of the telescope. For photographic observations the light which has traversed the above system is collected by an objective of short focus in the focal plane of which are superposed the real image of the nebula and that of the ring. Finally, it is possible to examine the image visually with an eyepiece.

We have made a practical application of this plan to the equatorial of the Observatory of the University of Marseilles. The objective has a diameter of 26 cm, and a focal length of 3.10 m. Having removed the eye-end of the telescope, we replaced it by the apparatus represented in Fig. 1. *A* is an eyepiece with two lenses forming an optical system of 4 cm focal length, the first focus of which is in the focal plane *F* of the telescope objective. On leaving this eyepiece, the rays of the nebula give an image at infinity, enlarged eighty times. The light then traverses the interference apparatus *B*, which gives its system of interference rings. A microscope objective *C*, of 4 cm focal length, forms in its focal plane *P* a real image of the nebula, of the same size as that which would be directly given by the telescope objective; this image is crossed by the interference fringes. For photographic observations, the plate is placed at *P*. In visual observations we see the superposed image of the rings and of the nebula through a second eyepiece *D* having a focal length of 2.5 cm; the nebula is then seen with an enlargement of 120, and the rings

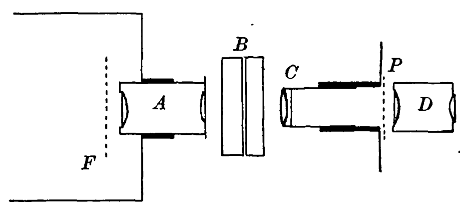

FIG. 1

with an enlargement of 1.6. The free aperture of all the lenses is such that there is no loss of light.

The interference apparatus is of the type having a fixed difference of path, which is called the *étalon interférentiel*.[1] It is difficult to apply this form of construction when the film of air has a thickness less than 1 or 2 mm; for thicknesses less than this the two silvered surfaces are simply separated by three bits of steel of suitable diameter cut from the same rod. Springs with an adjustable pressure hold the silver surfaces against the pieces of steel and permit us to obtain parallelism.

The quality of the silver surfaces is of great importance. If they are too thick, the proportion of the light transmitted is very small; if they are too thin, the reflecting power is very little, and the interferences are not sharp. We have employed films silvered by impact at the cathode. Each of the surfaces transmits for the green mercury line about 20 per cent of the incident light and reflects 50 per cent. The interference apparatus may be inclined at a slight angle to the beam of light, which permits us to displace the system of rings with respect to the image of the nebula.

The total weight of everything attached to the tube of the telescope is only 3 kilograms.

We have examined only the nebula in *Orion*. Observing visually, we established without difficulty the existence of interference rings, in successively employing differences of path of 0.6, 2, and 5 mm. The rings thus observed are due to the ray at λ 5007, which is the most intense of the visible lines in the spectrum of that nebula.

We have also made an attempt at a photographic observation. In order not to increase the time of exposure in this first experiment we worked with all the rays without interposing any absorbing medium. Since the objective of the equatorial was achromatized for the visual rays, it was impossible to obtain a good image of the stars and of the nebula: the images of stars are circles of considerable diameter, although we had made the setting for the mean of the photographic rays. That had no effect on the sharpness of the rings, the images of which are given solely by the objective *C*. With a difference of path of 0.6 mm and an

[1] Ch. Fabry and A. Perot, *Astrophysical Journal*, **15**, 81, 1902.

exposure of $1\frac{1}{4}$ hours, we obtained perfectly sharp rings on a Lumière Sigma plate. Furthermore, the images of the stars destroy part of the field. The strongest rays in the photographic spectrum of the nebula of *Orion* are the hydrogen line, γ, at λ 4341, and the line of unknown origin at λ 3727; the rings photographed result from the superposition of the rings due to these two rays.

These first attempts have no other object than to show the possibility of applying our method. We hope to be able to employ it with instruments which are more powerful and better adapted to the purpose, in particular with a reflecting telescope. All the difficulty from lack of achromatism would thus be avoided. Furthermore, the use of an objective of large diameter allows us to employ a great amount of light. It would then be possible to combine the different lenses of the apparatus in such a way that the ratio of aperture to focal length of the instrument should be large, which would permit short exposures of the photographs without making the images too small. This result may indeed be obtained whatever is the ratio of the aperture of the telescope objective. Under the conditions of our experiments, the ratio of aperture of a complete system would be only 1:12; with a large objective, it would probably not be impossible to go to 1:4.

The use of the interference method will be able to yield certain interesting results. It would be easy to measure the wave-lengths of the different rays with great precision and thus to derive the radial velocity of the object, in using the hydrogen lines. The variations of wave-length from one point to another would give us the circulatory movement of the gas. The determination of the limits of interference would give the size of the different lines; and an indication as to the temperature would be furnished by the size of the hydrogen lines, while the size of the lines of unknown origin would give us a clue to the atomic weight of the gas which forms them.

We have been able to make this experiment by the courtesy of M. H. Bourget, director of the Observatory of the University of Marseilles, who has been good enough to permit us to employ the equatorial of the observatory and has given us his personal assistance in its use. We extend to him our very sincere thanks.

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