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THE FÉRY SPECTROGRAPH UPDATED

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RESUMEN. El Espectrógrafo de Féry tiene una propiedad muy interesante, a saber, conjuntar en una sola pieza óptica las características de prismas, espejos y lentes. La mayor ventaja la presenta en el ultravioleta, ya que ahí las pérdidas de luz son insignificantes, porque el número de superficies aire-cuarzo es mínimo y el grosor del material óptico usado es relativamente pequeño. Este espectrógrafo, altamente eficiente, cuando se combira con detectores modernos se convierte en un instrumento astronómico muy poderoso. Se mencionan algunas aplicaciones interesantes.

ABSTRACT. The Féry spectrograph uses a single quartz optical unit that combines the characteristics of prism, mirror, and lenses. Hence, it presents its greatest advantage in the ultraviolet, where loss of light is minimized by the small number of air-quartz surfaces and the rather small thickness of optical material used. This very high efficient spectrograph, combined with modern detectors, results in a very powerful instrument for Astronomy. A few attractive astronomical applications are described, as well as how to overcome its vertical astigmatism.

Key words: TELESCOPES — OPTICS

I. INTRODUCTION

Spectrographs are major astronomical tools for analizing the emission and absorption spectra of stars, galaxies, quasars and other celestial objects. The wavelength resolution and the total efficiency are two important properties to be considered in the design of an astronomical spectrograph.

The wavelength resolution is defined as the minimum wavelength difference necessary for two features in the spectrum to appear separate on the record. In most cases of astronomical interest, the detector employed to record the spectrum has a limit of resolution larger than 0.015 mm (most photographic plates, reticons, CCD, mepsicron, and so on); thus, most of the time, the wavelength resolution is set by the detector, rather than by the optical resolving power. Since to some extent, the quality of the spectrum depends on the width of the slit, then for a given focal length of the camera, this width should be such that it does not upset the resolution set by the detector.

Now for a given slit, the efficiency of a spectrograph can be defined by the ratio of the amount of light going through the slit, and that arriving into the detector. Therefore it is clear that if the slit is wide enough to allow all the stellar light to pass through and at the same time, the light losses by absorption, reflection, and scattering are very small, then the efficiency of the spectrograph will be high.

Another quantity that is related to efficiency, especially when a photographic emulsion is used as detector, is the speed, which has been formally defined by Bowen (1962) as 'the ratio of the energy impinging on unit area of the spectrum record to the energy a one angstrom wavelength range, received by a circular area on the telescope mirror of unit diameter'. In many cases the limiting magnitude of a star, or other celestial object, is directly determined by the spectrograph speed.

A Schmidt Camera with an objective prism produces stellar spectra with great efficiency, because it has a minimum number of reflecting and refracting surfaces; moreover it has no slit (or one of infinity width). However, a definite limit to the exposure time is set by the fogging caused by the night sky. Thus, for instance, stellar spectra around m = 12 have been obtained with the Tonantzintla Schmidt Camera, with a linear reciprocal dispersion of 250 A/mm at $H\gamma$ - $H\delta$, approximately. In a slit spectrograph, the slit eliminates most of the night sky; light that sets the limit to exposure time of an objective prism instrument.

II. THE FERY SPECTROGRAPH

Taking into account the above Mendoza and Ortega (1978) have designed a spectrophotometer, which allows all stellar light go through the slit. It consists optically of only three pieces, a collimator mirror, a plane grating, and a single mirror camera. The detectors are, an RCA 1P21 photomultiplier, for the blue region of the spectrum; and a Si-diode (EG-G SND 140) for the near infrared region. Ortega (1986) has shown that the efficiency of this spectrophotometer is independent of the f/ratio of the camera. Moreover, since he uses the apparatus to measure total absorptions of spectral lines, the quality of the spectrum needs not be high.

This indicates that the spectrograph designed by Féry (1911) can be used in Astronomy with a great success. This instrument is based upon the device of autocollimation developed by Littrow, which can be employed with both, prisms and plane gratings in which the collimating lens or mirror is also used as camera. A very ingenious application of this autocollimation principle was made by Fery, who designed a single quartz optical unit that combines the properties of prism, mirror and lenses. That is, in a single optical piece are merged the main optical parts of a spectrograph, namely, collimator, dispersing element, and camera. The Féry optics is illustrated in Figure 1.

A review of prism's characteristics, including those with curved faces has been made by one of us (C.X.M., 1986). Thus herein will suffice to state that the front face of the prism in the Féry spectrograph is usually a cylindrical surface with axis vertical, so figured that diverging rays from the slit all strike it at the proper angle for minimum deviation. The rear surface, also a vertical cylinder, is usually aluminized to give high reflection in the ultraviolet. The spectrum is brought into horizontal focus on a surface of fairly curvature, as shown in Figure 1.

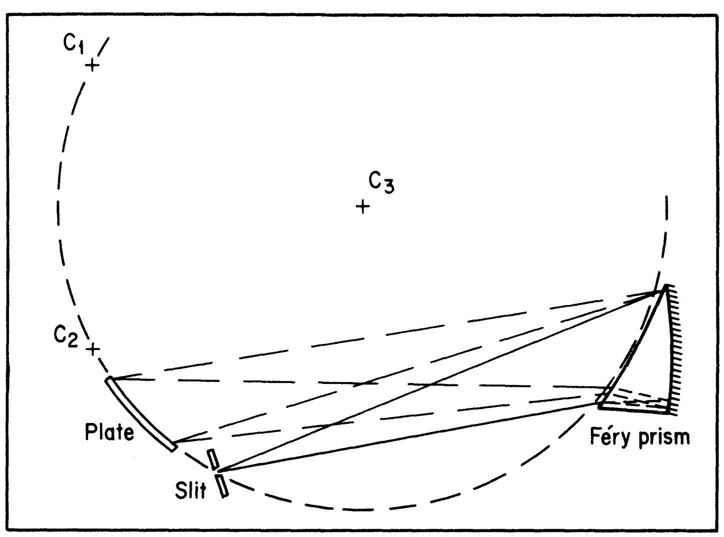

Fig. 1. The Féry Optical Design. C_1 is the center of curvature of the front prism face. C_2 that of the rear reflecting face. The two centers, the slit, and the detector all lie on a circle with center at C_3.

The conjugate focus of a point on the slit obtained by a narrow bundle parallel to the edge of the prism is not the same as in the direction of the dispersion, this result in a certain amount of astigmatism, as in the concave grating of Rowland. Altogether the Féry spectrograph presents its greatest advantage in the ultraviolet, where loss of light is minimized by the small number of air-quartz (or other glass for the prism with high transparency in the ultraviolet) surfaces and the rather small thickness of optical material used.

III. CONCLUSION

Because of their great light efficiency, single-order spectrum, ruggedness, and ease of manufacture prisms are preferred as a dispersing medium in spectrographs. Thus the Féry mounting with only one optical element competes advantageously with concave and plane grating spectrographs.

The astigmatism present in the perpendicular direction to the dispersion is of no importance, if the spectrograph is used as spectrophotometer to measure total absorptions, or if the instrument is employed for starlike work with modern electron detectors, where the starlike spectrum record is a digital image, and the comparison spectrum is another digital image, both starlike and comparison spectra are obtained with practically no widening, that is, no astigmatism for all practical purposes.

For extended objects one may proceed either by obtaining several spectra, one for each region of interest, with a certain loss of effectiveness, or to use a long slit to obtain straight spectral line, but astigmatic which can be corrected at the computer, especially if the spectrum record is a digital image.

Hence the Féry spectrograph can be of great utility in Ultraviolet Astronomy, both from the ground and from the space. An additional attraction of this instrument is its low cost, scanty and easy maintenance.

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