Identification of Orders and Ghosts in Grating Spectra by Diffracting Slits

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SPECTRA taken with grating spectrographs show overlapping orders and always exhibit more or less intense ghost lines. Advantageous as the overlapping of orders is for many investigations, it is sometimes troublesome to assign the individual lines to their proper orders. The use of light filters is successful for relatively long waves, but is in the best case a method of negative selection. A better method would be the direct indication of the wave-length on the plates. This can be achieved by utilizing the length direction of the spectral lines as a coordinate for a diffraction pattern which is narrow enough to exhibit several orders. The distance between the diffraction minima is then a measure of the wave-length. The various overlapping orders differentiate themselves by the widths of their patterns which have the ratios of small integers; to wit, the reciprocals of the orders. The Lyman ghosts, on the other hand, do not fit generally into this system. The widths of their diffraction patterns indicate their true wave-lengths, and thus allow one to determine the period of the grating error by comparison of the wave-lengths of the Lyman ghosts with those of the neighboring lines.

The diffraction pattern was created in two different ways according to the mounting, or better to the astigmatism in the investigated region. In the strongly astigmatic Paschen mounting with about 48° angle of incidence, a mask with a slit one mm wide was placed immediately over the grating, the slit being horizontal. If d is the width of this diffracting slit, r the distance from there to the plate, and s the distance from the central maximum to the first minimum in the diffraction pattern of the spectral line of wave-length λ, then $s=r(\lambda/d)$. With d chosen as one mm, a wave-length $\lambda=4000\text{A}$ gives a distance $2s$ of about six mm between both first diffraction minima if a grating of twenty-one-foot radius is used. A point source at the spectrograph slit was used to define the pattern well.

A spectrum taken with this arrangement is shown in Fig. 1. A section of the iron arc exhibits lines in the third and fourth orders. The third minima of the denser lines are juxtaposed to the fourth minima of the enclosed triplet, so that the ratio of wave-lengths is four to three, the shorter wave-length appearing in the fourth order, the longer wave-length in the third order. The wave-lengths with the orders given in parentheses are as follows: 4132.06 (3); 3099.9 (4); 3100.31 (4); 3100.67 (4); 4134.68 (3). In Fig. 2 an example of overlapping second- and third-order iron lines is

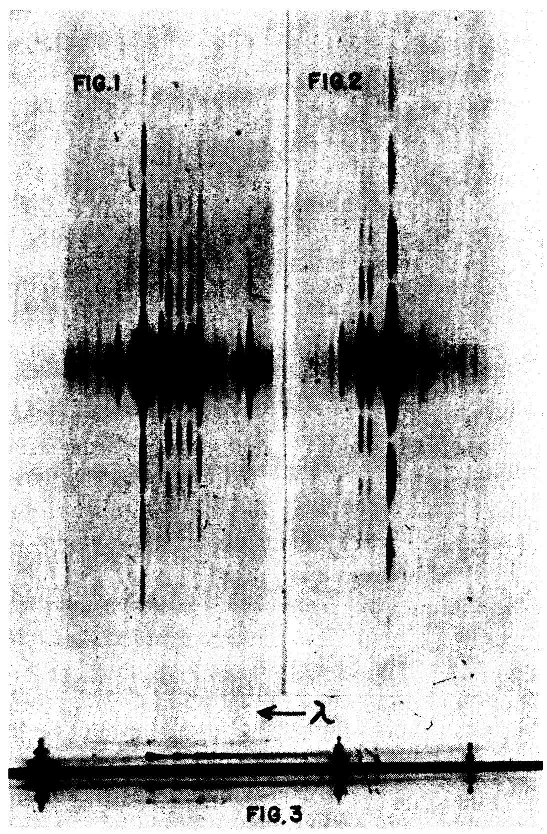


FIG. 1. Lines belonging to the overlapping third and fourth order of the iron arc, identified by the relative widths of their diffraction patterns.

FIG. 2. Lines belonging to the overlapping second and third orders of the iron arc, identified by the relative widths of their diffraction patterns.

FIG. 3. Ghosts of spectral lines (here of the cyanogen band) are characterized by the abnormal widths of their diffraction patterns, in comparison to the neighboring lines. The diffraction is caused by a system of sixty slits across the grating in a Wadsworth mounting.

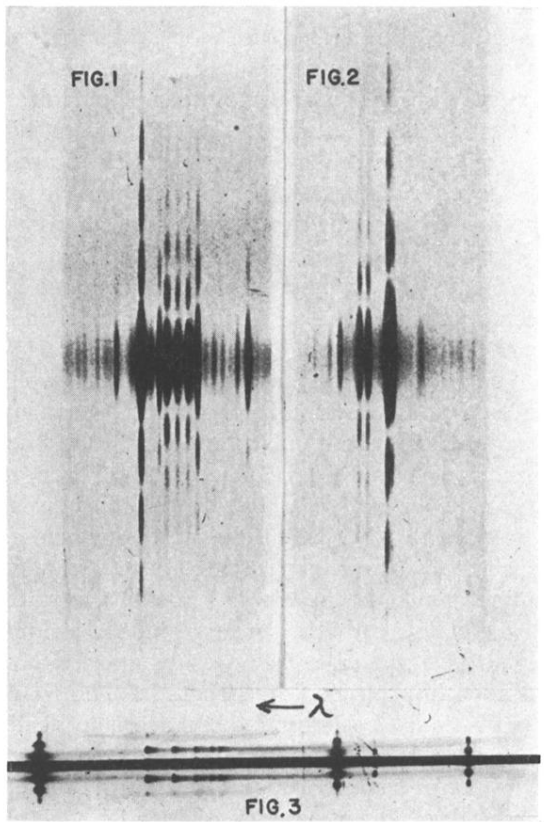
shown, the wave-lengths and orders being: 4957.61 (2); 3305.98 (3); 3306.36 (3).

In the stigmatic Wadsworth mounting, the length of the rulings does not influence the size of the image on the plate; hence multiple slits may be used before the grating for producing the diffraction along the spectral lines. We used a system of sixty slits made by winding six-mil copper wire around two screws with a pitch of thirty-two per inch that were separated by six inches. This transmission grating with a surface two inches by five inches was placed over the concave grating. The intensity gained by using most of the ruled concave grating surface and by the narrower maxima due to many slits allowed us to follow the pattern as far as twenty maxima to each side of the central image.

This arrangement was therefore used to determine the wave-lengths of weak ghost lines. In qualitative analysis in which carbon electrodes in air are used, the cyanogen bands are strong and even their ghosts are troublesome. In Fig. 3, the ghost of the cyanogen band 3883A is shown with some cadmium lines for reference. The different spacings in the cadmium line diffraction pattern and the ghost line pattern have the ratio three to four; therefore the ghost appears at three-fourths of its true wave-length, and every other strong line is to be suspected of having ghosts at three-fourths of its wave-length.

The Lyman ghosts are frequently not focused at the Rowland circle, and therefore the line structure, such as narrow multiplets or hyperfine structure satellites, cannot be used for an easy identification. At the suggestion of Mr. T. O'Donnell, long exposures were taken around the direct reflection of a 30-foot grating in a Paschen mounting. Weak Lyman ghosts of $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{9}$, 2/9, 3/9 the true wave-length were easily identified.

Useful as this method is for separating orders and for recognizing ghost lines in grating spectra, it has its limitations. These are caused by the low intensity of the extended diffraction patterns on the one hand and by the restriction of the length of the entrance slit on the other. They result in a very long time of exposure. In detail, a slit not longer than one mm can be used, and this means that only 1/25th of the usual amount of light falls on the grating. Furthermore in a circle mounting the grating is partly covered to produce diffraction, whereas the diffracted image is spread out on the plate. For distinguishing overlapping orders, the weak lines can hardly be expected to exhibit their secondary maxima that theoretically have not more than 4 percent of the peak intensity of the central maximum. For identifying ghosts with only a small fraction of the intensity of the parent line, considerable overexposure of the parent line is required. Astigmatism of the spectrograph can be overcome either by using a single diffracting slit at the grating, or by having either a source or a virtual source at the secondary focus of the grating for the angle of emergence to be photographed.



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