Echelle Ripple Function Determination

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SUMMARY

A new empirical formulation of the discrepancy in the behavior between the IUE Echelle Ripple function and the simple theory is compared to the previous formulation. Parameters obtained from least squares fits to two different IUE targets observed with the short wavelength photometer are examined. The results indicate that the grating "constant" is actually a parabolic function of order which differed between the two stellar observations examined.

I. Introduction

The simple theory for the echelle blaze correction (echelle ripple function) is that it is a parameterized sinc function for each order with the maximum at the central wavelength. Turnrose and Harvel (1980) reported that the empirical data in the case of the International Ultraviolet Explorer (IUE) indicated that the actual function is less steep and varies as a complex function of order. The IUE reduction process has used an adjustable parameter which obviates the need for understanding the sources of the complications to the theory (Turnrose and Harvel 1980). In this report, I suggest an alternative formulation, with an adjustable parameter which is simply a factor of the sinc function argument. I have produced a fitting routine which I use to show that this parameter is independent of echelle order. I fit the echelle grating constant to many orders of two different stars observed with the short wavelength photometer, and here report on its behavior as a function of echelle order.

The effects of linearity and sensitivity problems are not considered.

II. Empirical Formulation

The simple theory of the echelle blaze correction gives the echelle ripple function (the ratio of the actual flux to the extracted net flux) as

$$R = \frac{\sin^2 \alpha X}{(\alpha X)^2} \qquad (1)$$

where

$$X = \frac{\pi m^2 (\lambda - \lambda_c)}{K} \qquad (2)$$

where m is the echelle order, λ is wavelength, K is the echelle grating constant (to be determined empirically), $\lambda_c \equiv K/m$ and $\alpha \equiv 1$. As Figure 1 shows, this function does not coincide with the observed echelle ripple. The object observed in Figure 1 is NCC 246 which is a sufficiently hot star with a sufficiently weak surrounding nebulosity that the effects of absorption lines on that part of the spectrum used cannot account for the failure of the simple theory.

Turnrose and Harvel (1980) sought to remedy this by multiplying $R(\lambda)$ of the simple theory by a factor of $(1 + aX^2)$ where a is an adjustable parameter and by replacing equation (2) by

$$X = \min \left| \frac{\frac{\pi m\ (\lambda-\lambda_c)}{K}}{2.61} \right| . \tag{3}$$

As can be seen in Figure 2, using the adjustable parameter improves the fit, but it is still not perfect, even when a is left a variable function of order. Instead, I have chosen to use equations (1) and (2) with α as a free parameter. Now the fit is excellent (see Figures 3-5). Note that because λ_c is related to K, the factor α does not merely rescale K.

Several orders of NGC 246 and of the cooler star NGC 2342 were fitted with both K and α as free parameters. α was found to have an order-independent value of $.85 \pm .02$, but K was found to depend upon order and differ in the two cases.

III. Empirical etermination of K

Fixing α at .85, the fitting routine was run for 56 orders of NGC 246 and 18 orders of NGC 2342. The results are shown in Figure 6 and 7 respectively. K is clearly not constant.

On the assumption that orders outside the range $72 \leq m \leq 115$ may give unreliable values of K due to cathode curvature and order overlap, K was determined as a parabolic function of order using only orders in that range. The results are the solid lines in Figures 6 and 7. The coefficients of the parabolic fit

$$K = a_0 + a_1 m + a_2 m^2 \qquad (4)$$

are given in the table below.

Table 1

Target	a_0	a_1	a_2
NGC 246	138260	-15.6812	.107170
NGC 2342	137680	-31.4938	.034601

We note that fitting K for the Turnrose-Harvel algorithm gives a qualitatively similar variation in K. We note that fitting K for the Turnrose-Harvel algorithm gives a qualitatively similar variation in K. This is unlikely to be due to the effect of the energy distribution in the source. Beekmans and Penston (1979) found that differences in energy distribution of the source alter K by less than .03%. Further, we find that the values of K obtained from Table 1 give reasonable agreement between adjacent orders (see the example in Figure 8). Thus, we have no sure explanation for the difference between targets. Heap (1981) attributes the difference to a dependence of the grating "constant" on the details of the registration of the image on the photocathode.

If the adjustable parameter in the new algorithm is indeed a constant, the IUE user need only vary K to optimize the echelle ripple correction for a given order and registration.

References

Beekmans, F. and M. Penston 1979, Unpublished Memo.

Heap, S. 1981, Private Communication.

Turnrose, B.E. and Harvell, C.G. 1980, International Ultraviolet Explorer Image Processing Information Manual: version 1.0 (Silver Spring, MD: Computer Science Corporation) CSC/TM-79/6301, Chapter 6.

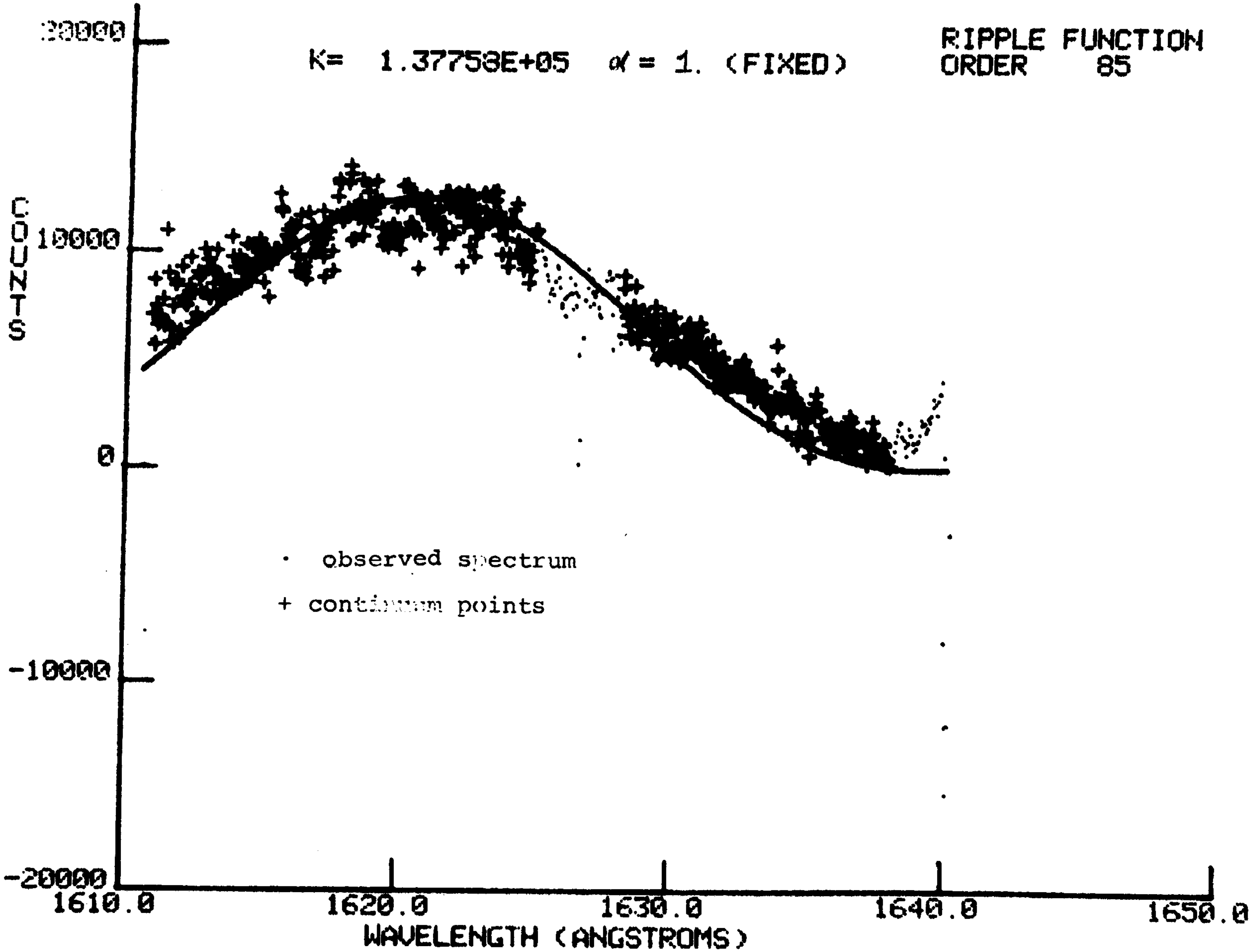

Figure 1. Least Squares Fit of Simple Theoretical Echelle Ripple Ripple Function to NGC 246 continuum (crosses).

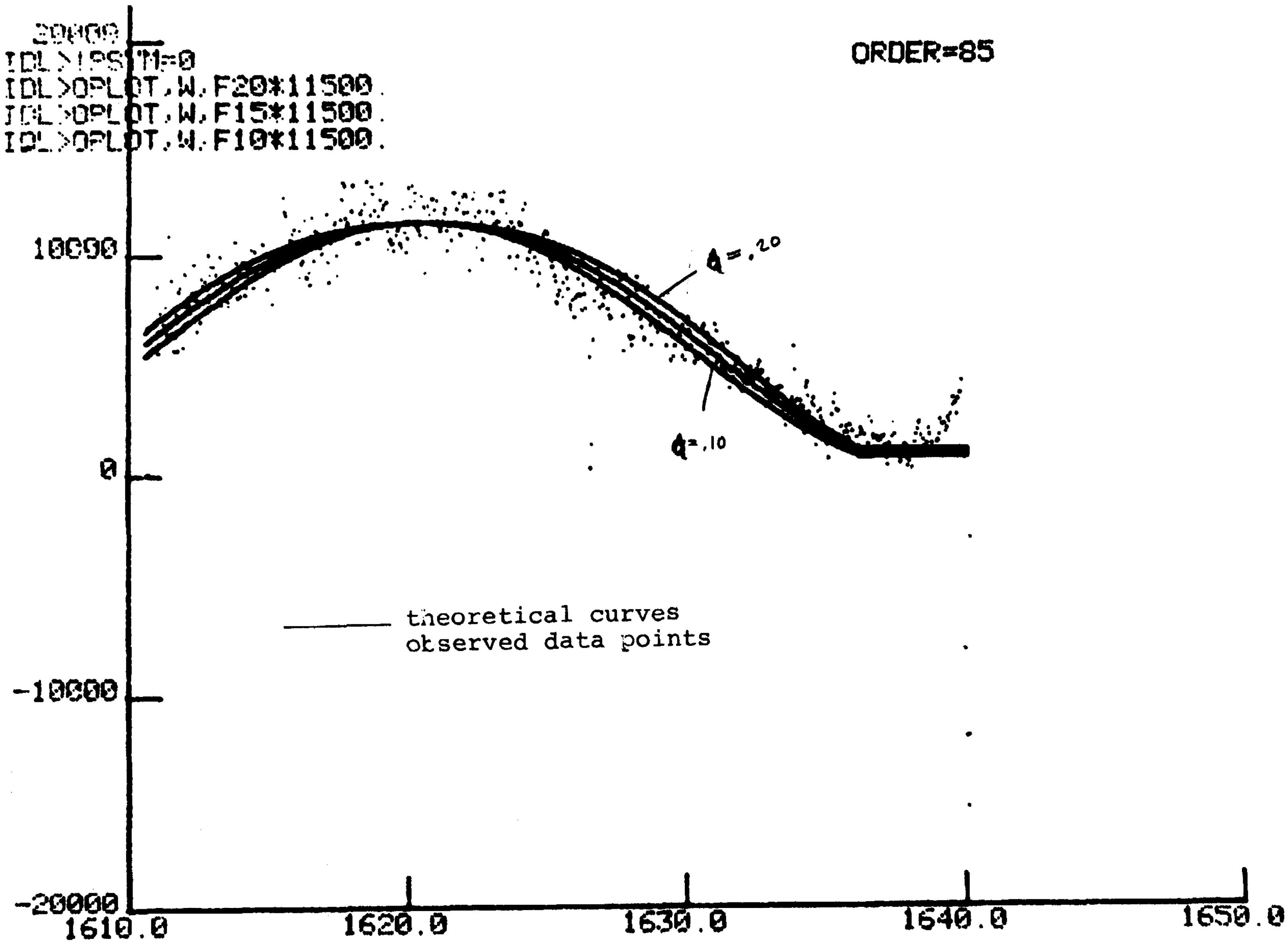

Figure 2. Turnrose-Harvel (1980) Ripple Function Fit to NGC 246 Continuum for a = .10, a = .15, and a = .20.

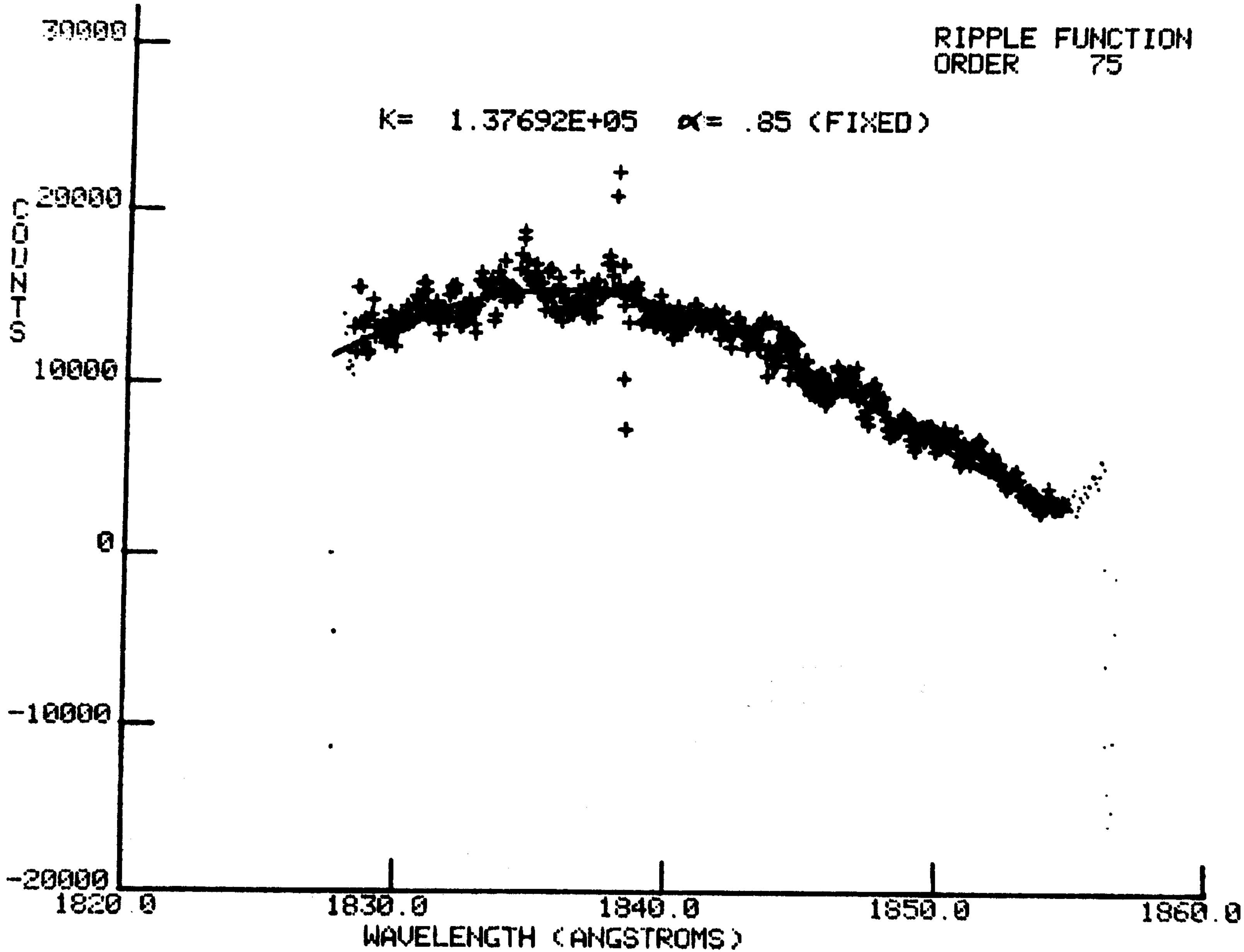

Figure 3. Least Squares Fit of Present Echelle Ripple Function (solid line) to NGC 246 continuum (crosses)

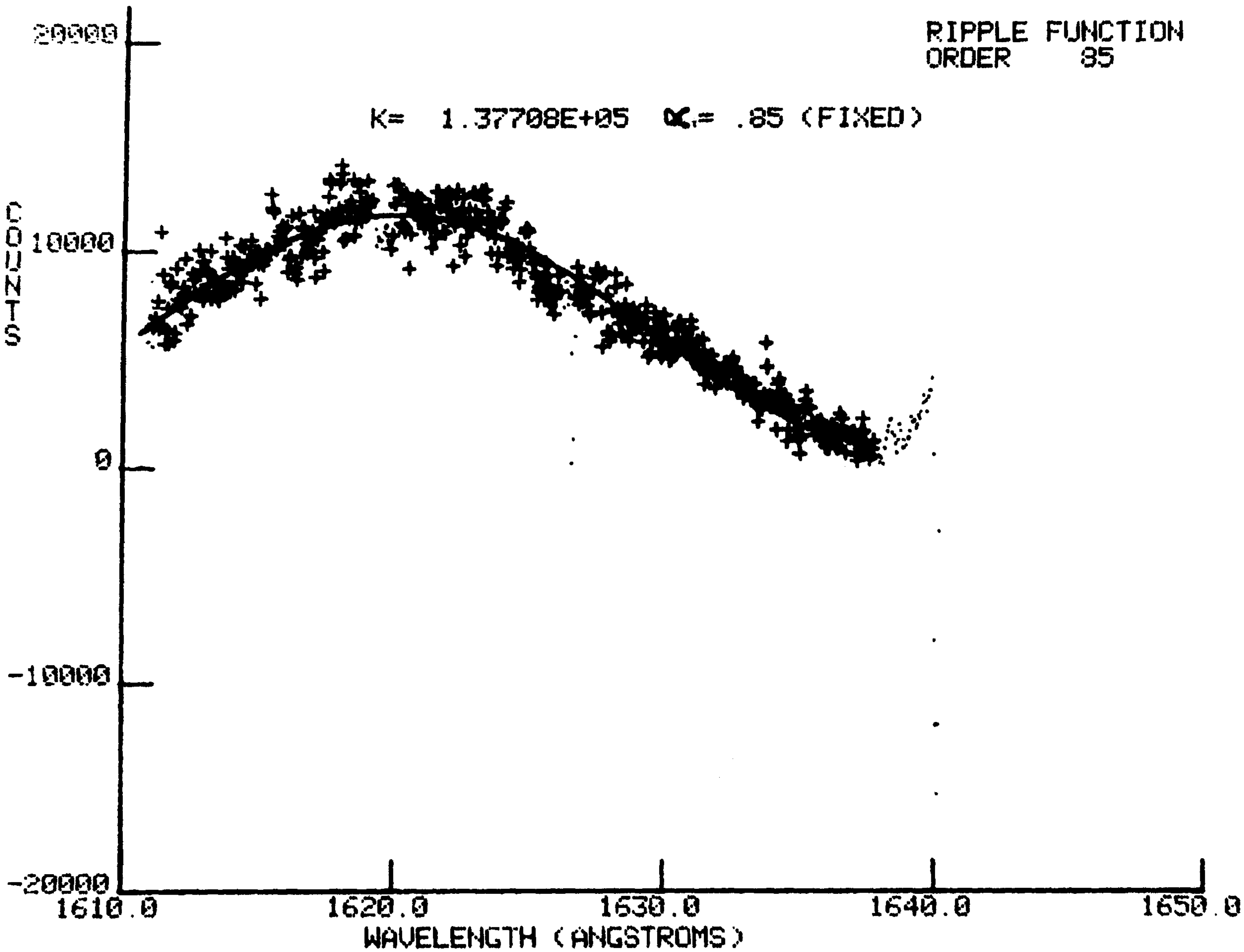

Figure 4. Least Squares Fit of Present Echelle Ripple Function (solid line) to NGC 246 continuum (crosses)

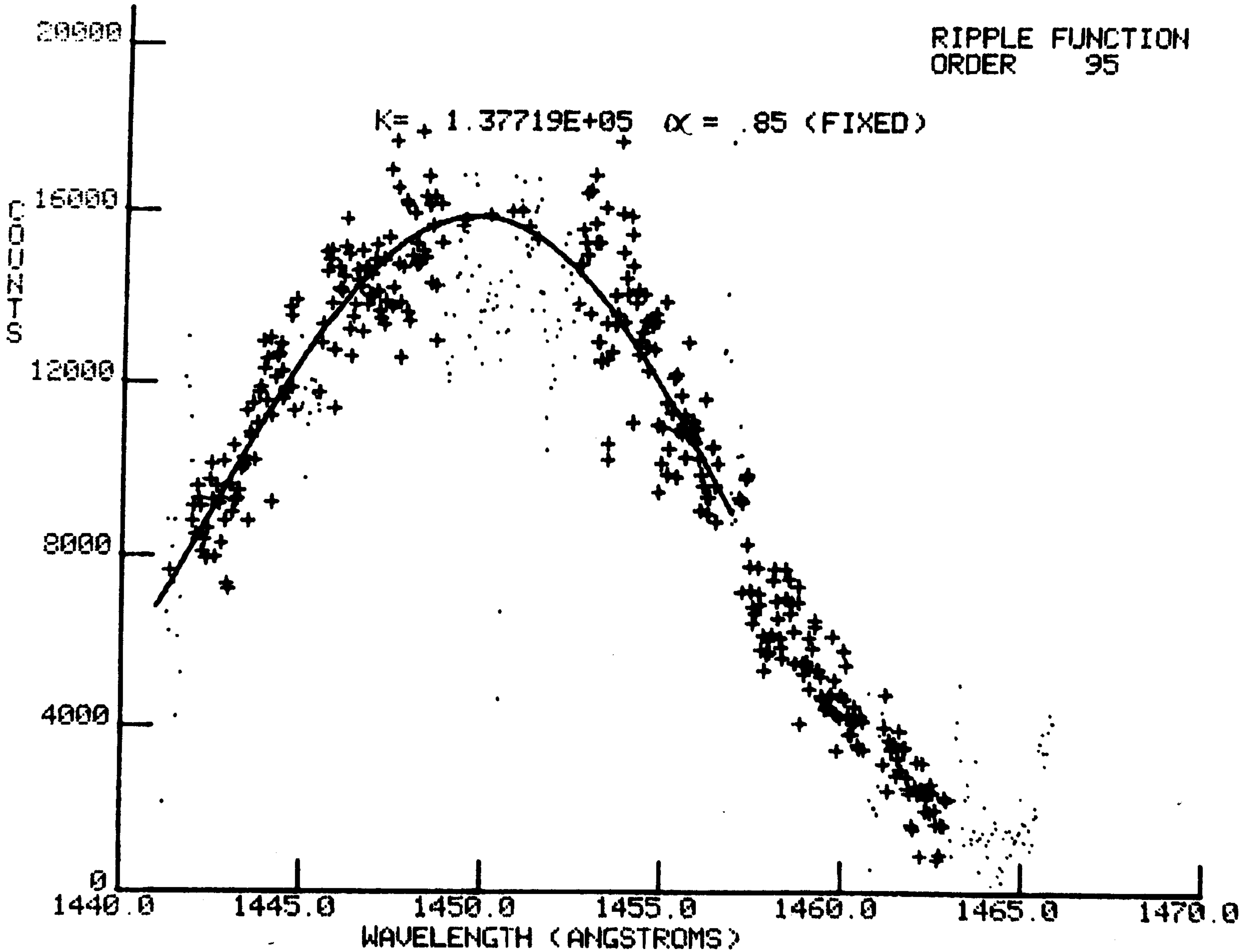

Figure 5. Least Squares Fit of Present Echelle Ripple Function (solid line) to NGC 246 continuum (crosses)

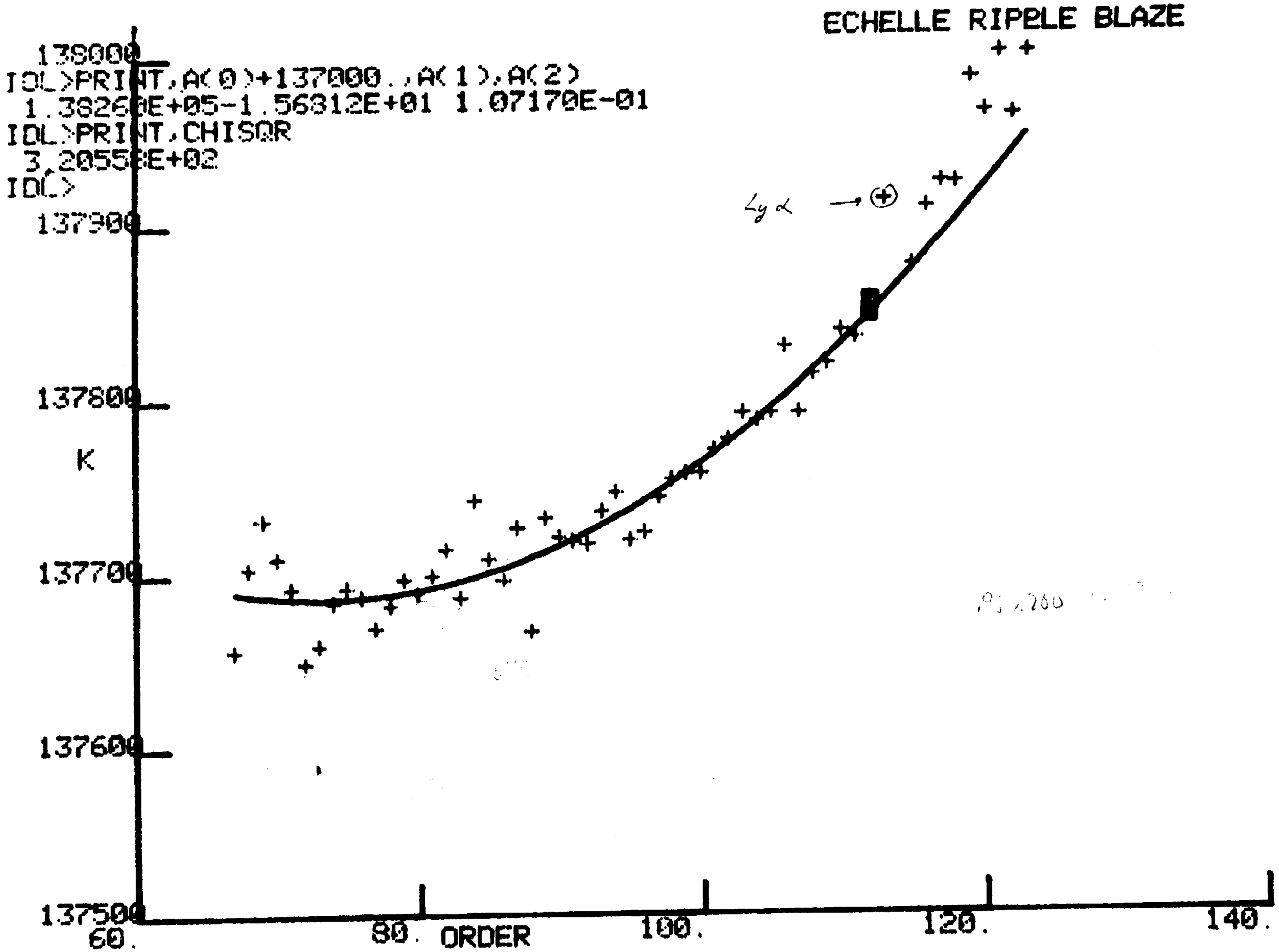

Figure 6. Echelle grating "constant" as a function of order derived from NGC 246 Observations. Points marked Ly α show unusual scatter because of uncertainties in removing Ly α line from continuum.

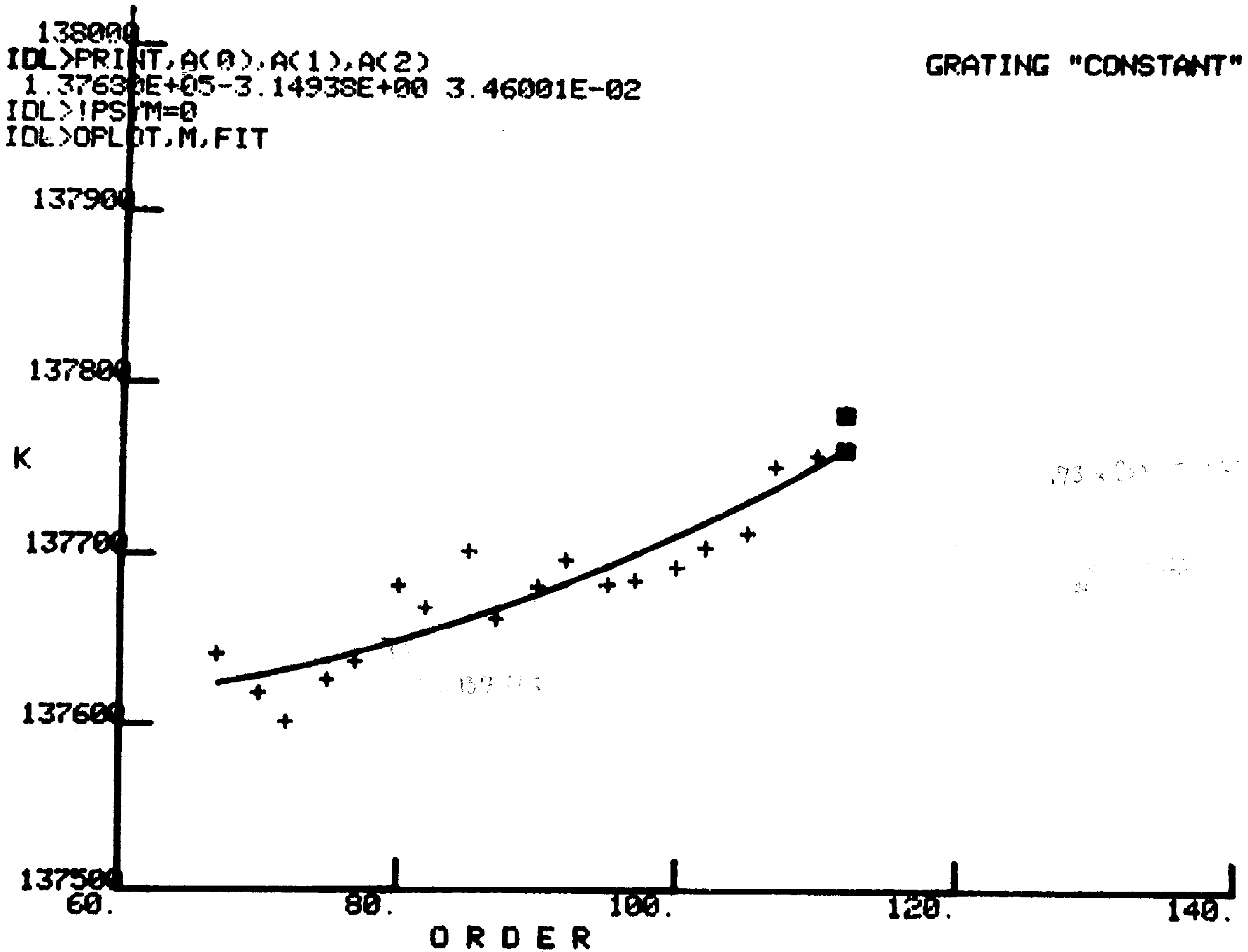

Figure 7. Echelle Grating "Constant" as a Function of Order Derived from NGC 2392 Observations.

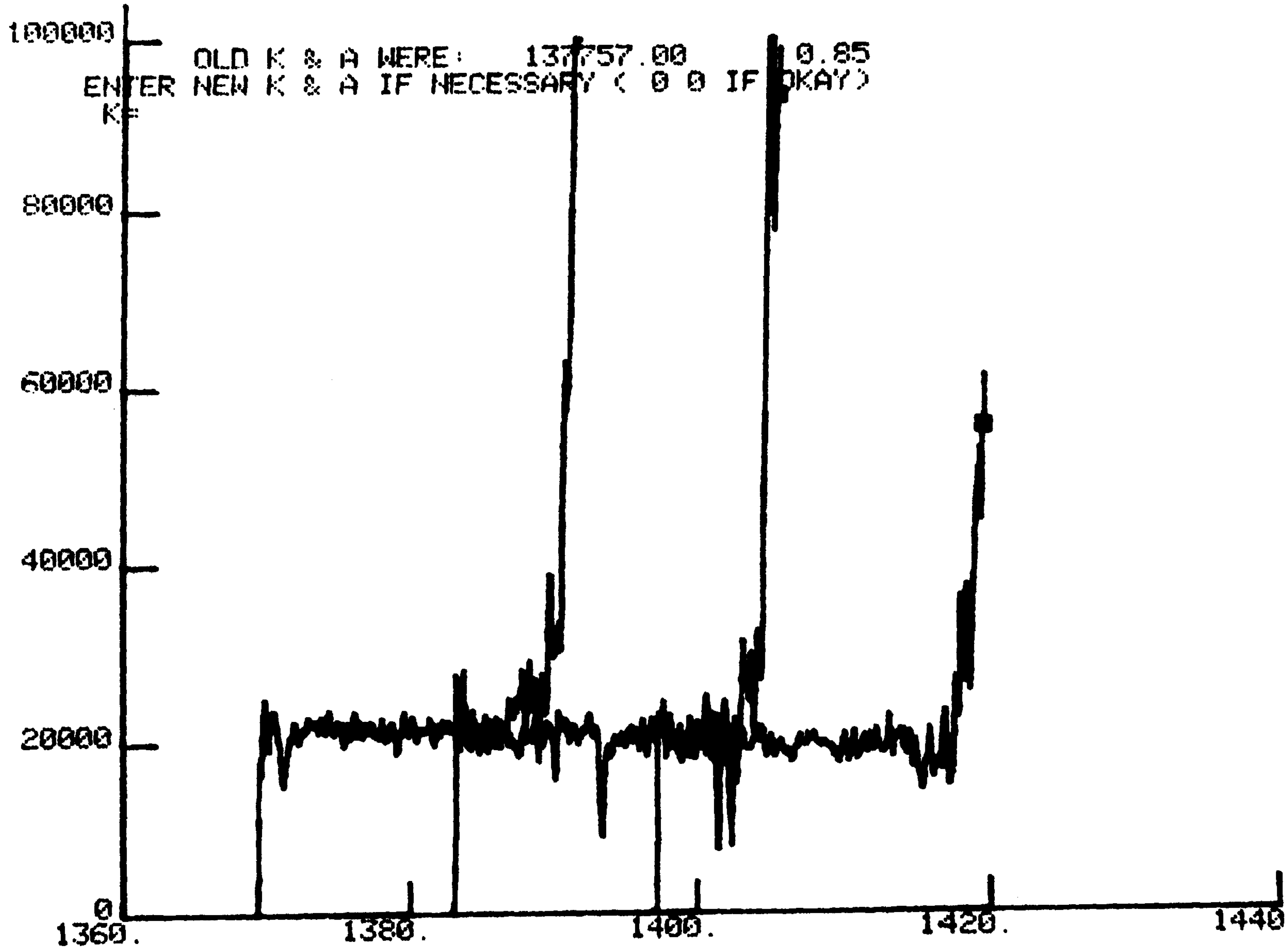

Figure 8. Interactive Output from Version of IUEHI3 Modified to Apply Present Ripple Correction to Three Orders (m=98, 99, and 100) of NGC 246 Observations.