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Correction for the STIS Echelle Blaze Function

Sara R. Heap and Thomas M. Brown[1]

Laboratory for Astronomy & Solar Physics, Code 681, NASA/GSFC, Greenbelt MD 20771

Abstract. Using the Early Release Observation of 9 Comae, we demonstrate an iterative method for correcting STIS echelle spectra for the effects of the echelle ripple. This analytic approach allows the actual spectrum of interest to be used in the determination of its calibration. The late F star 9 Comae is not an ideal candidate for this method, due to the many absorption lines present in its E230M spectrum, yet, given this difficulty, the method still works quite well.

1. Introduction

Because of the square format of modern imaging detectors, high-dispersion spectrograms are often obtained as echellograms, in which the spectrum is broken up into several orders arranged as horizontal stripes on the detector. This spectral mode provides broad overall wavelength coverage while retaining high spectral resolution. In doing so, it produces a characteristic efficiency along an order known as the echelle blaze function, or more simply, the echelle ripple, because of its characteristic shape. Figure 1 shows a schematic.

The associated calibration problem is to correct each order for the echelle ripple before merging the spectral orders together to form a single, linear spectrum. There are two approaches to ripple correction. The one most often used by spectroscopists at ground-based observatories is an empirical approach. After extraction of an order and subtraction of the inter-order background, the net spectrum of the target is divided by the net spectrum of a spectrophotometric standard observed in the same grating mode. The continuum can be further flattened through polynomial fits to the continuum, if necessary.

Space observatories generally take an analytic approach, in which the shape of the echelle ripple is described by a *sinc* function with appropriate fitting constants. Correction is made by multiplication by the inverse of the ripple function. The fitting constants are derived from observations of spectrophotometric standards, usually stars with a strong, rather flat continuum and weak spectral lines. The analytic approach is both feasible and practical because of the stable response of spectrographs in space and the fixed (usually small) number of grating settings that observers are allowed to use. Operations are more efficient, since calibration observations need be obtained only infrequently as part of the overall calibration program of a spectrograph.

2. Description of the Method

In this paper, we demonstrate the application of Barker's (1984) method, one of the analytic methods for correcting the echelle ripple. As a test case, we use the STIS E230M spectrogram of the late F star, 9 Comae (HR 4688, HD 107213) observed by STIS as one of the Early Release Observations (Heap et al. 1997). Figure 2 shows the raw echellogram.

[1]NOAO Research Associate

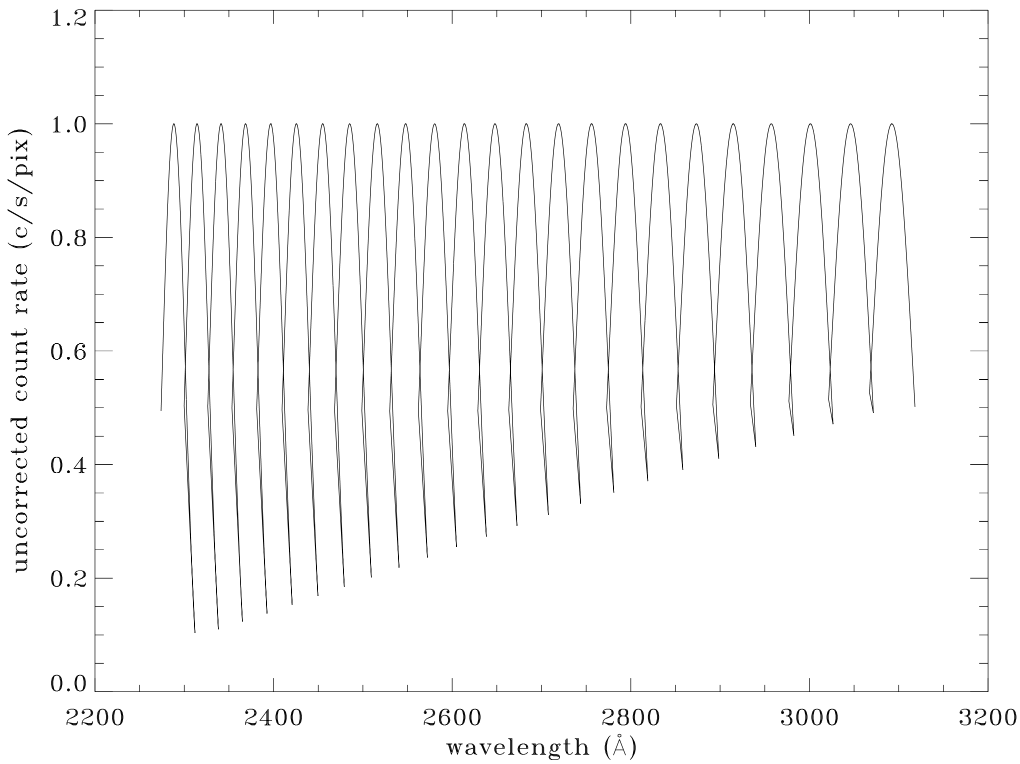


Figure 1. A schematic of the count rate measured from a flat continuum source, after over-plotting the E230M orders without correcting for the echelle ripple.

The spectrum spans the wavelength interval from 2274 Å to 3120 Å at a resolving power R=30,000 (10 km s^{-1}). Wavelength increases to the right within a spectral order, and from top to bottom (order $m = 66$ to order $m = 89$). The detector is large enough to accommodate the full length of each order, so the redundant spectral coverage by adjacent spectral orders is easily visible, i.e., a spectral feature at the right (long wavelength) end of order m is also visible at the left end of order $m + 1$.

Since the spectrum of 9 Comae was the first spectrum of an external source obtained by STIS in the E230M mode, the spectrum of the star itself had to be used to derive the echelle ripple function. With its rich absorption line spectrum, 9 Comae is not an ideal calibration source. Nevertheless, it was possible to derive the echelle ripple function by imposing the requirement that where two spectral orders overlap, the two orders must give the same flux. This requirement is the principle behind Barker's (1984) iterative method.

The echelle ripple function, R, is given by

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

where

$$X \equiv m\frac{1 - \lambda_c}{\lambda}$$

and where the order number m and the central wavelength of the order, λ_c, are related through the echelle "constant" $k \equiv m\lambda_c$. The other grating constant, α, controls the width of the ripple function. Unlike k, α does not seem to vary with spectral order. For IUE,

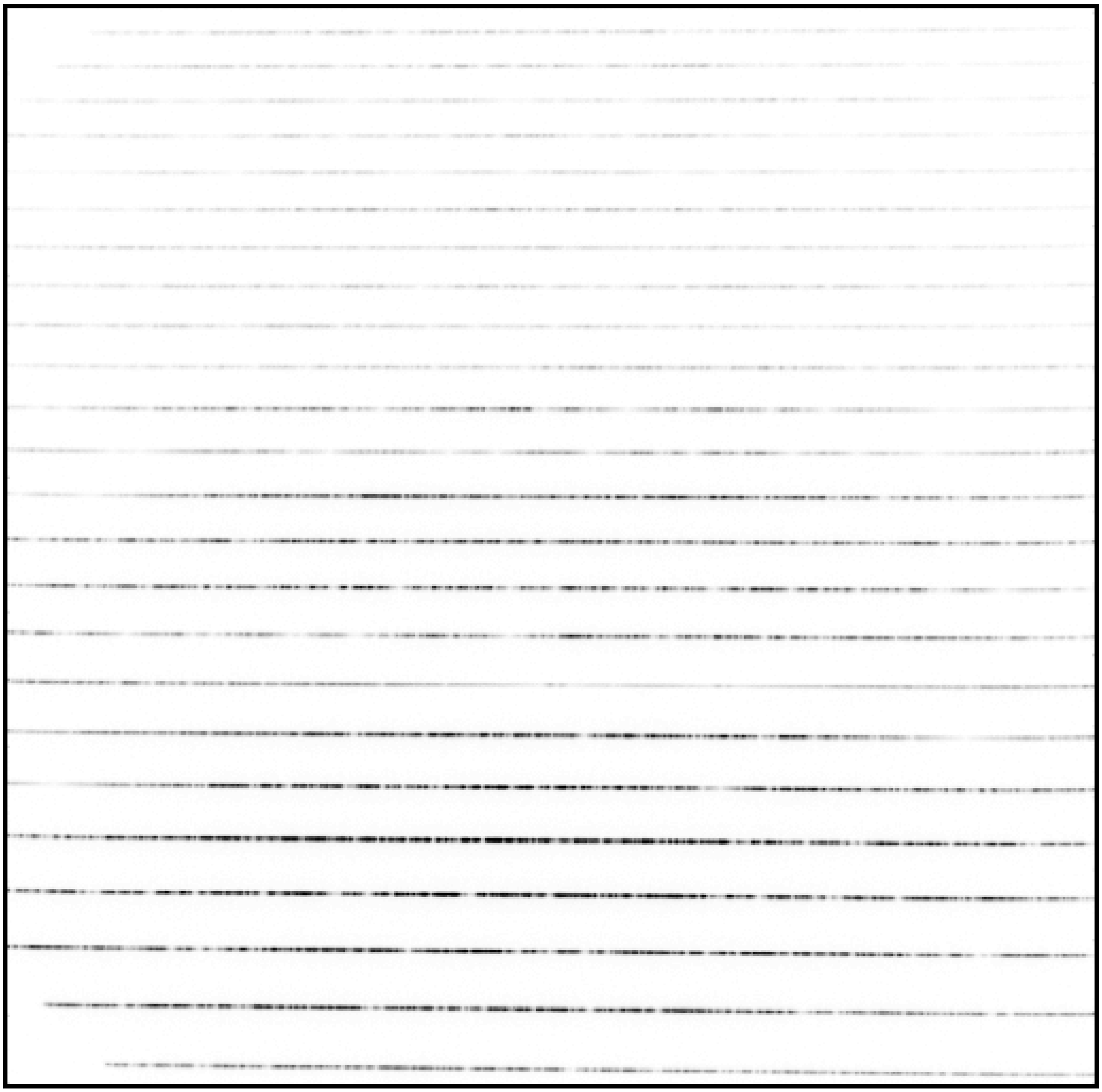
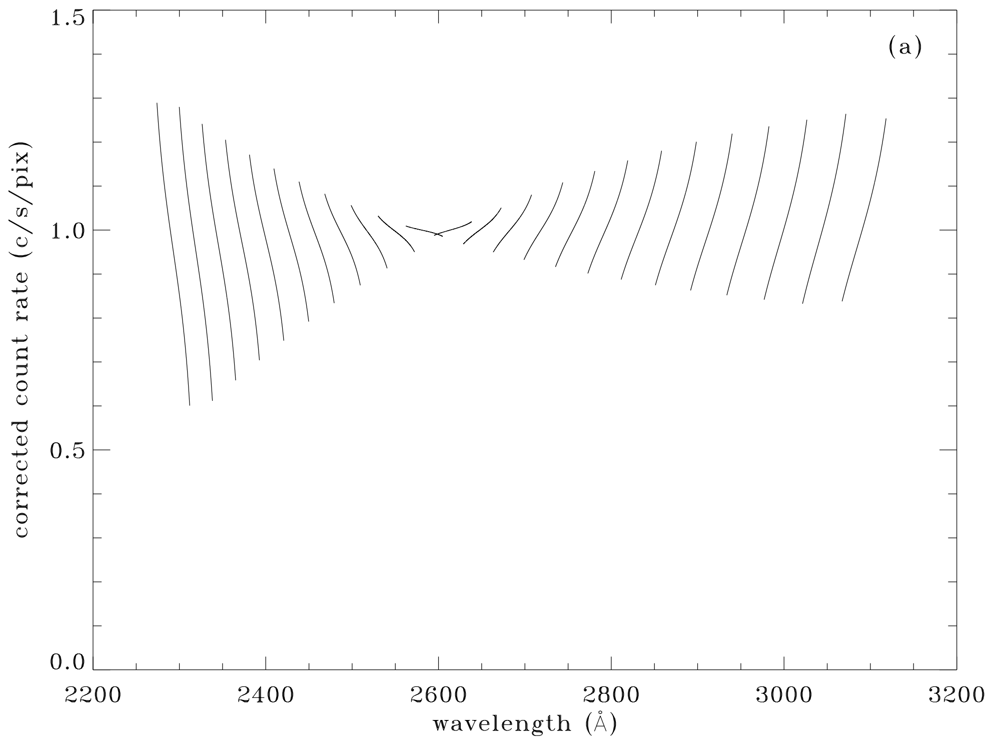


Figure 2. STIS echellogram of 9 Comae. The gray-scale is reversed so that the brightest regions are black. Wavelength increases to the right (within an order) and down (from order to order).



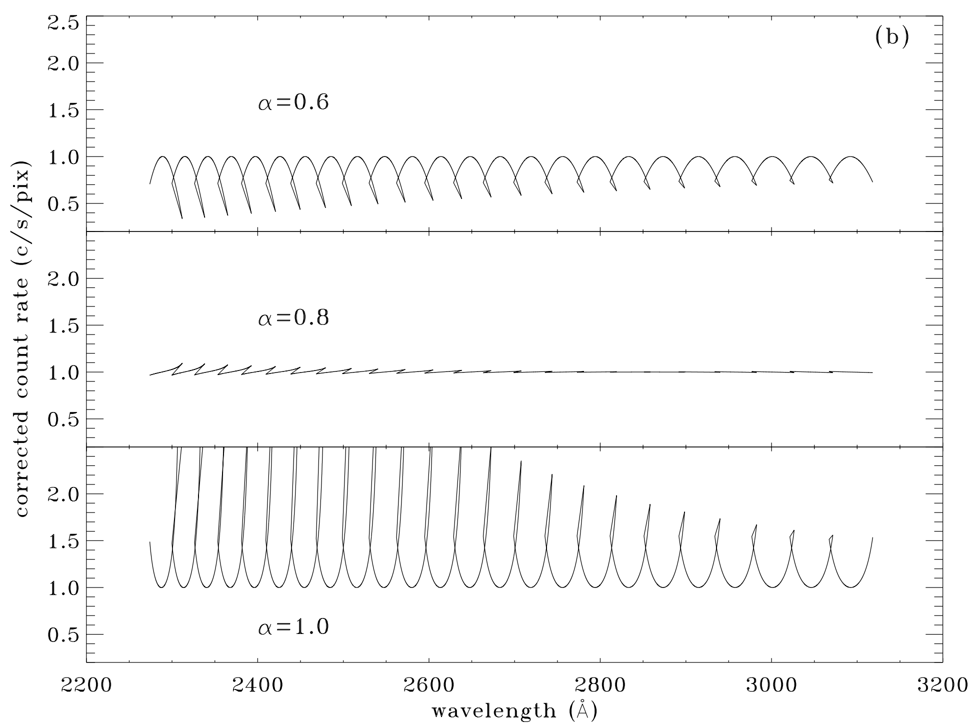


Figure 3. The effect of k and α on the correction to the echellogram. The top plot (a) shows the corrected count rate after assuming a constant k for all orders. The bottom plot (b) shows the effect of varying α on the corrected count rate.

the KPNO echelle, and the CASPEC spectrograph on the ESO telescope, α is a constant between 0.75 and 1.0.

In Barker's method, three spectral orders are treated at one time. First, the regions of overlap between the middle order and the two adjacent orders are determined. Then the value of k is adjusted iteratively until the middle order gives the same flux as the adjacent orders in the two regions of overlap. If k is incorrect, the spectrum veers up to the right or left. Figure 3a shows the effect of assuming a constant k. Similarly, the value of the order-width constant, α, must be adjusted to keep the corrected spectrum from looking scalloped (α too large) or ripple-shaped (α too small), as shown in Figure 3b.

The scheme followed for the E230M spectrum of 9 Comae was:

1. Use Barker's iterative method to get k_m for each order (Figure 4).
2. Make a polynomial fit to k_m to get $k(m)$ (Figure 5).
3. Use trial and error to estimate α.
4. Repeat steps 1–3 with the new value of $\alpha = 0.80$.

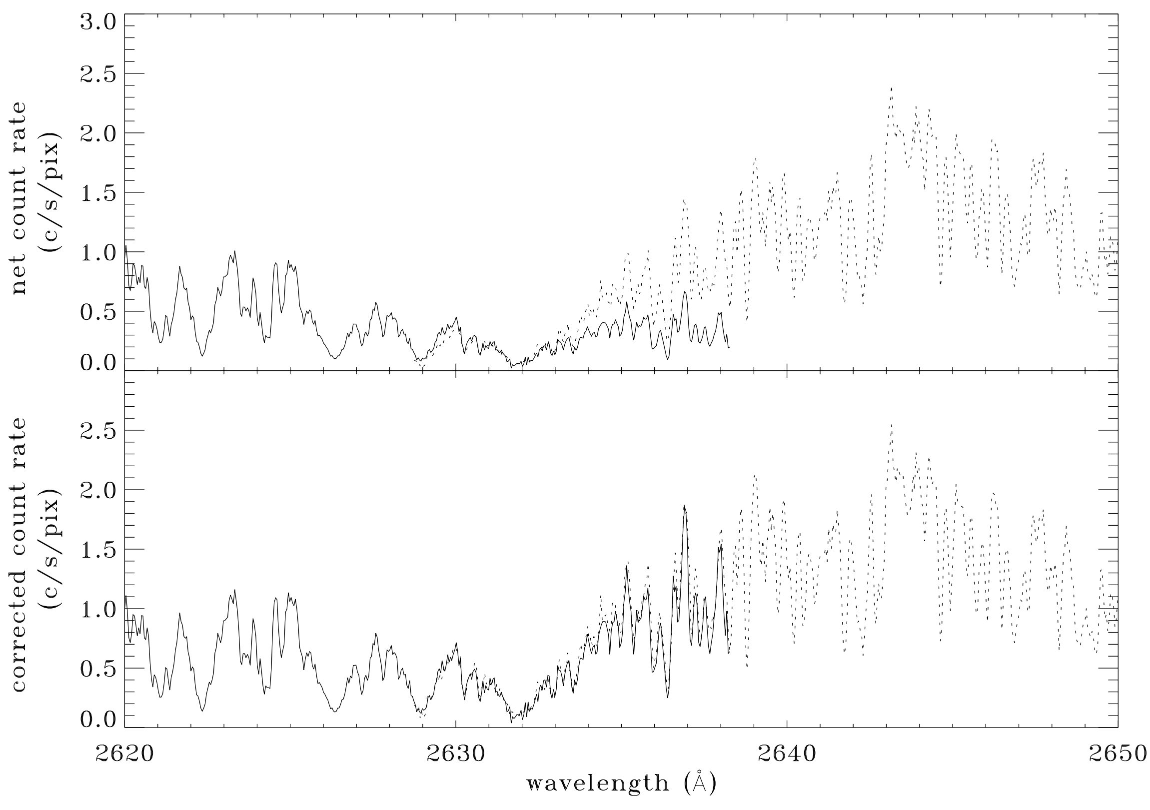


Figure 4. The overlap region for orders 77 (solid) and 78 (dashed), before (top panel) and after (bottom panel) iterating to find k_m.

3. Conclusions & Future Work

This calibration is preliminary, since it does not take into account most of the complexities of real echelle spectra. First, there is the problem of estimating the net fluxes. If there is significant grating scatter or if there are significant wings to the point-spread function (MAMA

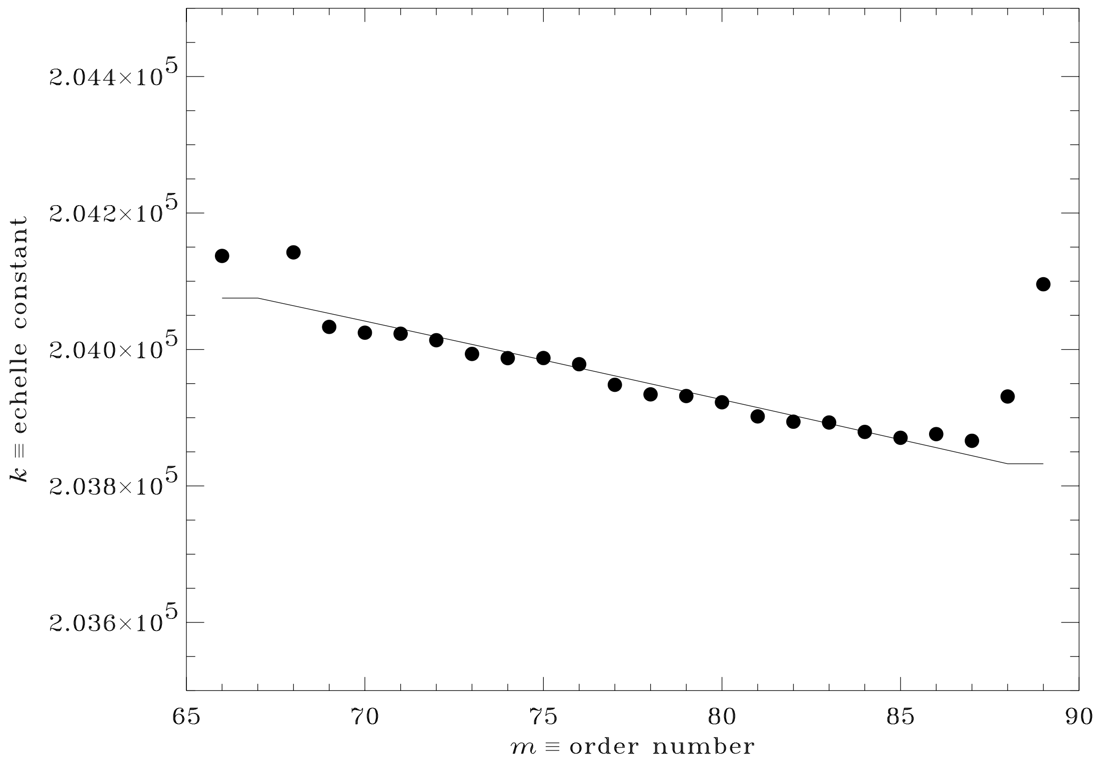


Figure 5. The value of k for each order (points) and the polynomial fit to these points (curve), as measured for the E230M observation of 9 Comae.

halo) then the background between the orders is not representative of the background under the spectral order itself. Secondly, there is the problem of non-uniformities. Vignetting or regions not fully corrected by flat-fielding will cause deviations from an analytic fit.

Despite the preliminary nature of this calibration, our demonstration shows that calibration by the analytic method is feasible. It is important to maintain a modular approach, e.g., isolate the vignetting from the echelle ripple, in order to understand the workings of the instrument and to identify the cause of possible changes in the future.

References

Barker, P. K. 1984, AJ, 89, 899

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