IUE Final Archive Calibration: SWP High-Dispersion Repeatability Analysis

Matthew P. Garhart
Computer Sciences Corporation
10000-A Aerospace Road
Lanham-Seabrook, Maryland 20706
Electronic-mail: calib@gorgon.gsfc.nasa.gov

25 July 1996

Introduction

Camera repeatability (*a.k.a.* reproducibility) analysis has been performed on SWP high-dispersion large-aperture data reprocessed with NEWSIPS. Repeatability is defined as the measure of the error in detected flux in multiple observations of the same object taken under identical conditions. A thorough understanding of how the *IUE* cameras behave from image to image is important when performing comparisons of spectral data and when looking for variability in an object. One must take into account the repeatability of a camera in order to ascertain the credibility of variations in spectral lines or continuum levels. That is, if the variation of a measured feature is less than the measured repeatability error, the results are meaningless. As a result of this concern, repeatability measurements have been computed in 1Å wavelength bins for optimally exposed SWP images. Repeatability measurements have also been made for both underexposed (*i.e.*, 40%, 60%, and 80% exposure levels) and coadded images (*i.e.*, 2 and 3 images).

Analysis

The method of analysis utilized in this study is similar to the one used in low-dispersion studies (*e.g.*, Bohlin 1978, Holm 1982, Oliversen 1983, and Garhart 1995). The data consist of groups of high-dispersion large-aperture point-source observations obtained during 1994 and 1995. The images within each group were taken on the same day using identical exposure times. This eliminates any errors that may be introduced by the time-dependent sensitivity degradation correction that is applied to the absolutely calibrated flux data. Although the correction is small, the fluxes have been corrected for camera head amplifier temperature (THDA) induced sensitivity variations (Garhart 1991). The data are listed in Table 2 and grouped by object and exposure level.

The fluxes for each order and within each group were ratioed to one another using all possible non-redundant combinations of images. So, for example, a group that had five images would yield four ratios per order. In the ideal case, one would expect the ratios to be unity. However, since the detectors are not perfect, the deviations of the ratios from unity represent the repeatability error for that particular ratio. The flux ratios were then binned at 1Å intervals in order to minimize the effects of random noise. The binned flux ratios were averaged in the following manner:

$$Average\ Repeatability\ Error_{\lambda} = (\Sigma \mid 1 - Ratio_{\lambda} \mid /n) \times 100$$

where n is the total number of ratios that are summed. This equation represents the average repeatability error for a particular wavelength bin and is expressed as a percent. Initially, each group of images was analyzed separately. The results from each group were compared and found to be in agreement, so the binned ratios from each group were averaged to produce a final set of repeatability values as a function of wavelength bin. For the repeatability analysis of coadded images, the fluxes from 2 or 3 images were averaged together before computing the ratios.

Conclusions

SWP repeatability errors as a function of wavelength for select orders are plotted in Figures 1–12. These plots indicate that for the well-exposed portion of the order the repeatability is fairly constant. For most orders, the long-wavelength end shows an abrupt increase in repeatability error. This trend is confirmed through examination of the MEHI (extracted 1-D spectra) file which clearly exhibits a decrease in flux starting at these wavelengths. A display of the SIHI (line-by-line) file also demonstrates a dearth of flux in this part of the camera.

Average repeatability errors as a function of order number fitted with a sixth-order polynomial are displayed in Figures 13–15. The averages were computed using the ten wavelength bins centered about the middle of the order. This region corresponds to the more sensitive section of an order. As a result, the averages are not biased by the less sensitive regions (*i.e.*, the right side of the camera). A definite dependence of repeatability error with order number is seen. In general, the errors slowly increase with order number until order 90. They then decrease slightly until order 109, at which point the errors rise rather quickly. The rates of increase and decrease depend very much on the exposure level, with the weaker exposures showing higher rates. The increase in repeatability errors for the higher orders is most likely due to the poorer signal-to-noise. The flux levels drop off dramatically above order 110 so that these areas tend to be noise-dominated. The average of the repeatability errors for orders 66 through 100 are slightly higher than the average low-dispersion error. However, the trend of improving repeatability error with increased exposure level is still true. As one would expect, coadding images greatly improves the repeatability errors. Coadding 2 or 3 images results in an overall repeatability of around 2% with some regions of the camera showing errors of less than 1%. Although insufficient images were available to perform a test, presumably the errors decrease as one coadds more images.

A study of the photometric stability in high dispersion was performed by Bohlin and Coulter (1982) using IUESIPS images. Their dataset consisted of 18 exposures of the standard star HD 120315 (Eta Uma) taken over a three year period. They report repeatability errors of 2.4% for order 83 at λ 1664Å, 3.7% for order 108 at λ 1277Å, and 4.6% for order 108 at λ 1283Å. We report repeatability errors of 2.3%, 4.8%, and 6.1%; respectively. Unfortunately, we were unable to repeat their work as there is no record of the images used nor of the exact method of analysis (*i.e.*, bin sizes).

Recent work by Cassatella (1996) involved the creation of the SWP high-dispersion absolute calibration and ripple correction using NEWSIPS data. In his analysis, he performed a cursory examination of the camera repeatability using several calibration standard stars (*i.e.*, BD+28° 4211, BD+75° 325, HD 60753, and G191 B2B). He quotes typical repeatability errors of 3% to 4% with some errors as high as 5% for HD 60753. The results of our analysis for orders up to 110 are well within this range.

A contrast of IUESIPS to NEWSIPS repeatability was performed by this author using the six images from the standard star HD 38666. The images were analyzed in an identical fashion so a direct comparison is possible. The results are summarized in Table 1. Although the IUESIPS repeatability results show slight (less than 1%) superiority over NEWSIPS for orders 85 and 90, the NEWSIPS data is vastly superior to IUESIPS at the higher orders.

Table 1: Comparison of IUESIPS and NEWSIPS Repeatability (%)

Order Number	IUESIPS	NEWSIPS
70	1.9	1.5
75	1.8	1.8
80	2.5	2.4
85	3.3	4.1
90	4.2	4.5
95	3.1	2.6
100	3.6	2.9
105	3.4	2.3
110	9.5	3.6
115	15.5	6.2

References

Cassatella, A. 1996, Private Communication

Bohlin, R.C. 1978, IUE NASA Newsletter, No. 2, 49

Bohlin, R.C. and Coulter, B.T. 1982, IUE NASA Newsletter, No. 19, 48

Garhart, M.P. 1991, IUE NASA Newsletter, No. 46, 65

Garhart, M.P. 1995, IUE NASA Newsletter, No. 55, 39

Holm, A.V. 1982, Advances in Ultraviolet Astronomy: Four Years of IUE Research, NASA CP-2238, p. 339

Oliversen, N.A. 1983, IUE NASA Newsletter, No. 23, 31

Table 2: SWP High-Dispersion Repeatability Images

Object Name	Spectral Type	E(B-V)	Image Number	Date (Yr/Day)	Exposure Time (secs.)	Exposure Level
HD 38666	O9.5 IV	+0.02	50234	1994/076	51.0	100%
			50235			
			50236			
			50237			
			50238			
			50239			
HD 142669	B2 IV-V	+0.04	55184	1995/183	32.0	100%
			55185			
			55186			
			55187			
			55188			
			55189			
HD 121263	B2.5 IV	−0.02	54848	1995/154	5.2	80%
			54849			
			54850			
			54851			
			54852			
			54853			
			54854			
			54855			

Table 2 (cont.): SWP High-Dispersion Repeatability Images

Object Name	**Spectral Type**	**E(B-V)**	**Image Number**	**Date (Yr/Day)**	**Exposure Time (secs.)**	**Exposure Level**
HD 121263	B2.5 IV	−0.02	54826	1995/152	3.9	60%
			54827			
			54828			
			54829			
			54830			
			54831			
			54832			
			54833			
HD 38666	O9.5 IV	+0.02	50240	1994/076	20.4	40%
			50241			
			50242			
			50243			
			50244			
			50245			
HD 142669	B2 IV-V	+0.04	55195	1995/184	12.8	40%
			55196			
			55197			
			55198			
			55199			
			55200			

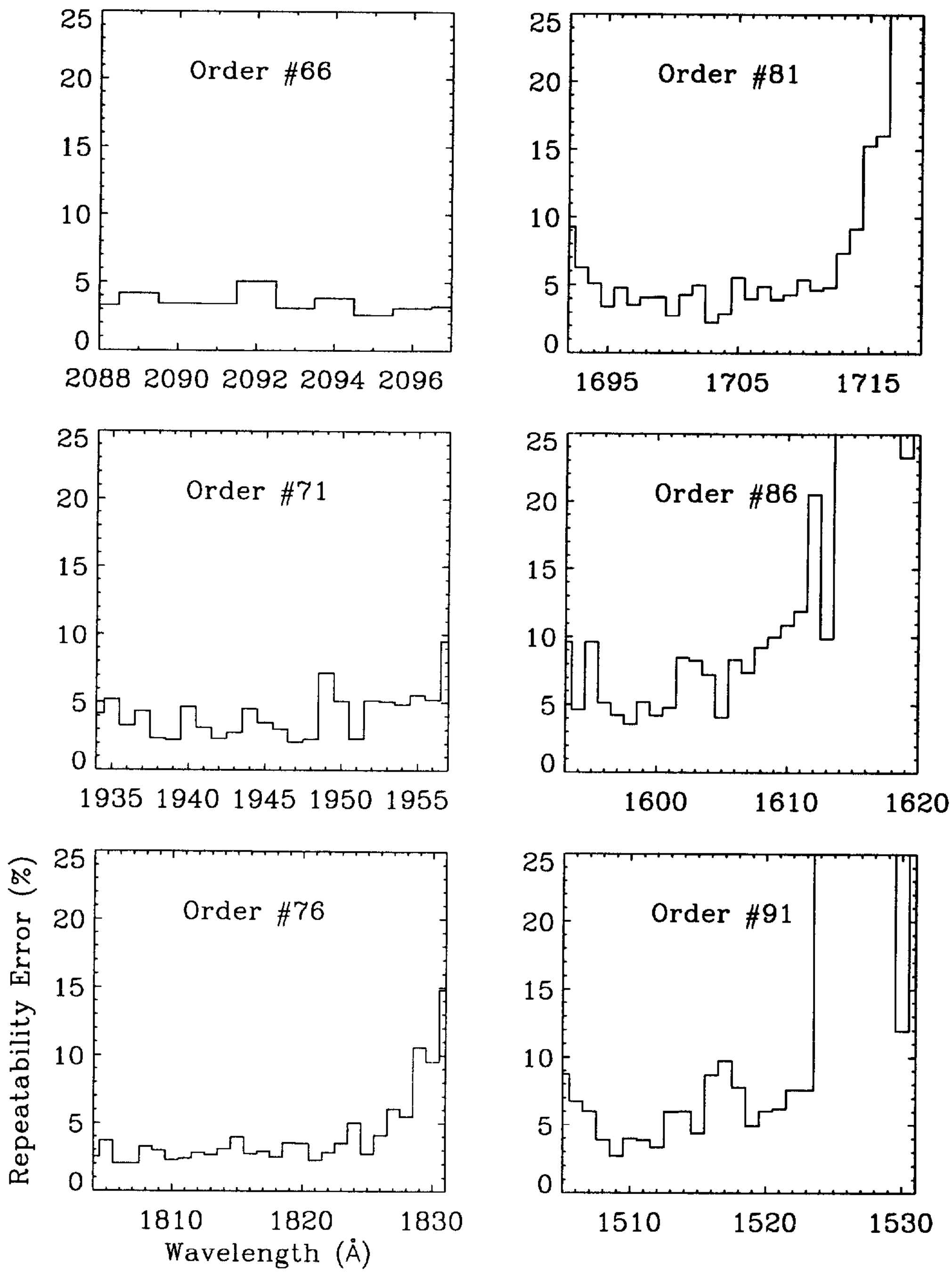

Figure 1: SWP high–dispersion repeatability as a function of wavelength for 40% exposures.

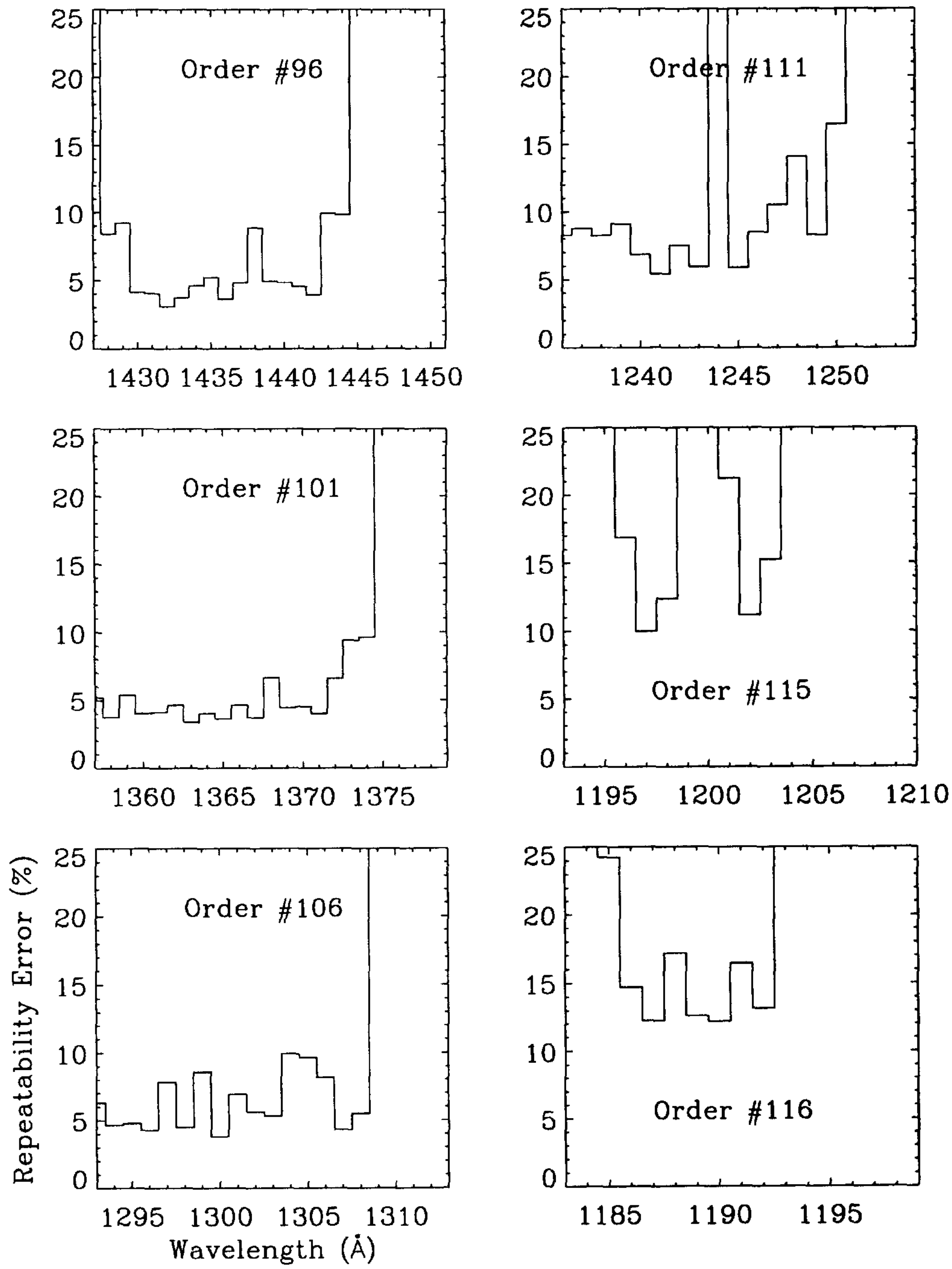

Figure 2: SWP high-dispersion repeatability as a function of wavelength for 40% exposures.

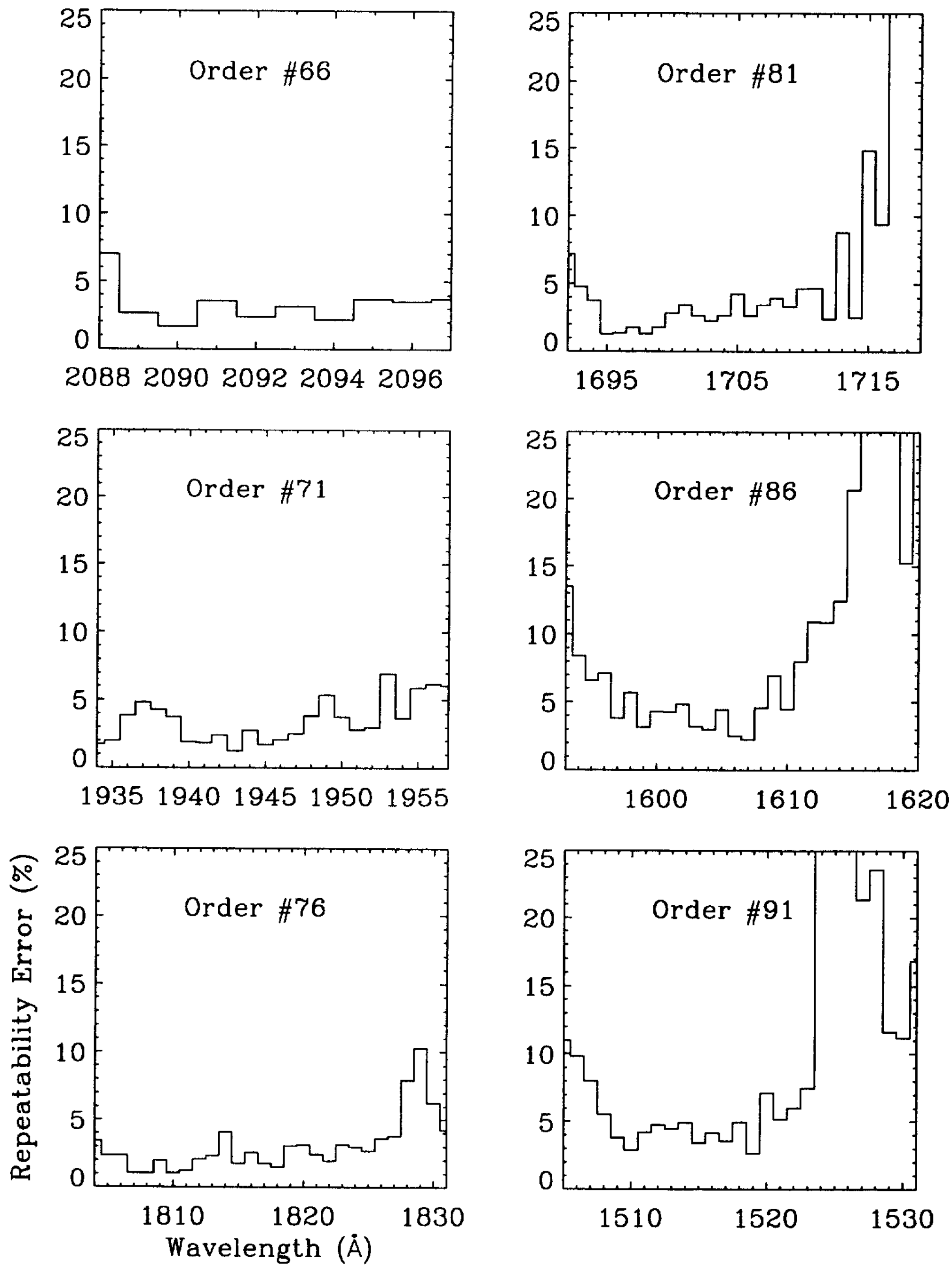

Figure 3: SWP high–dispersion repeatability as a function of wavelength for 60% exposures.

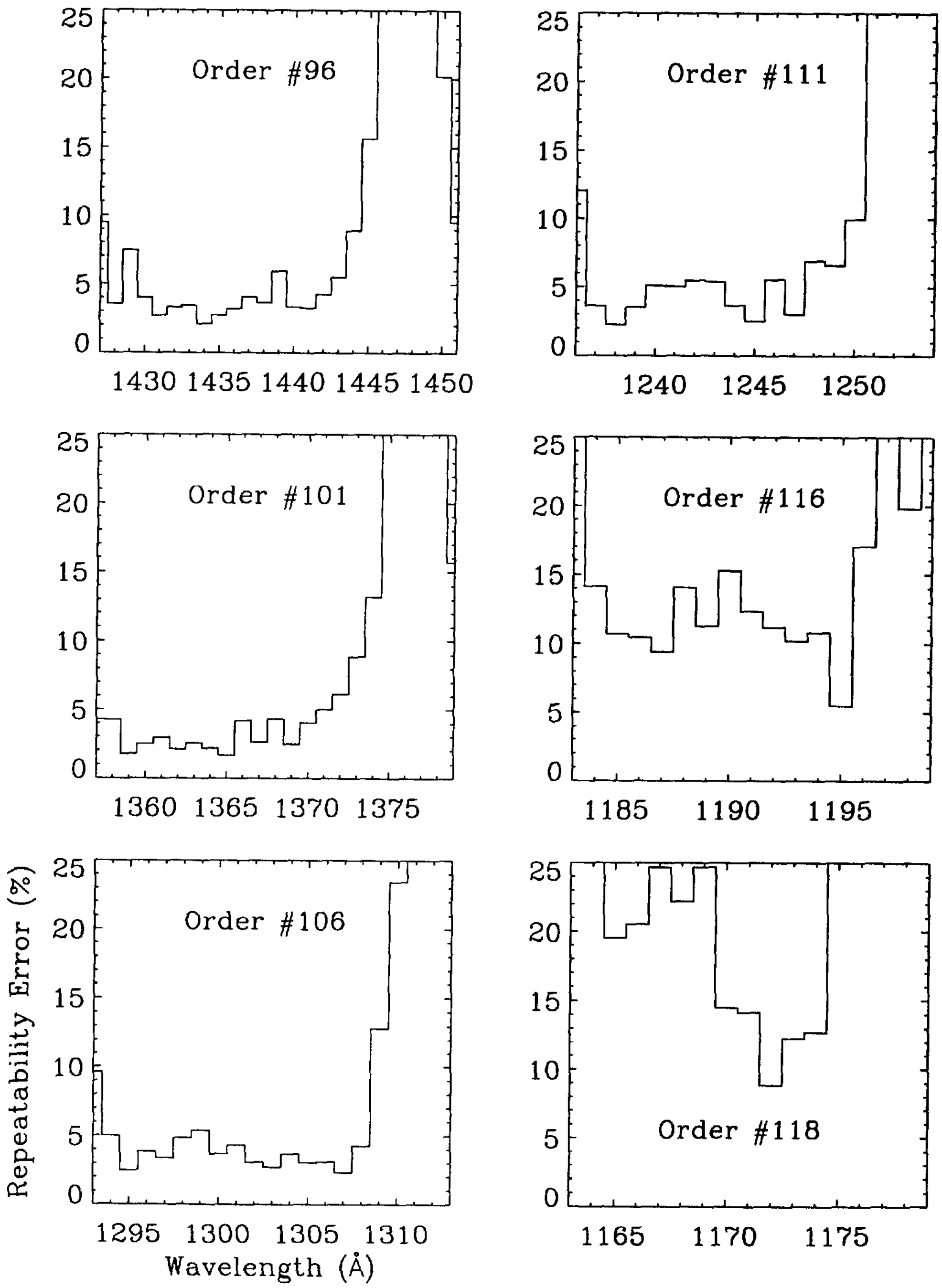

Figure 4: SWP high-dispersion repeatability as a function of wavelength for 60% exposures.

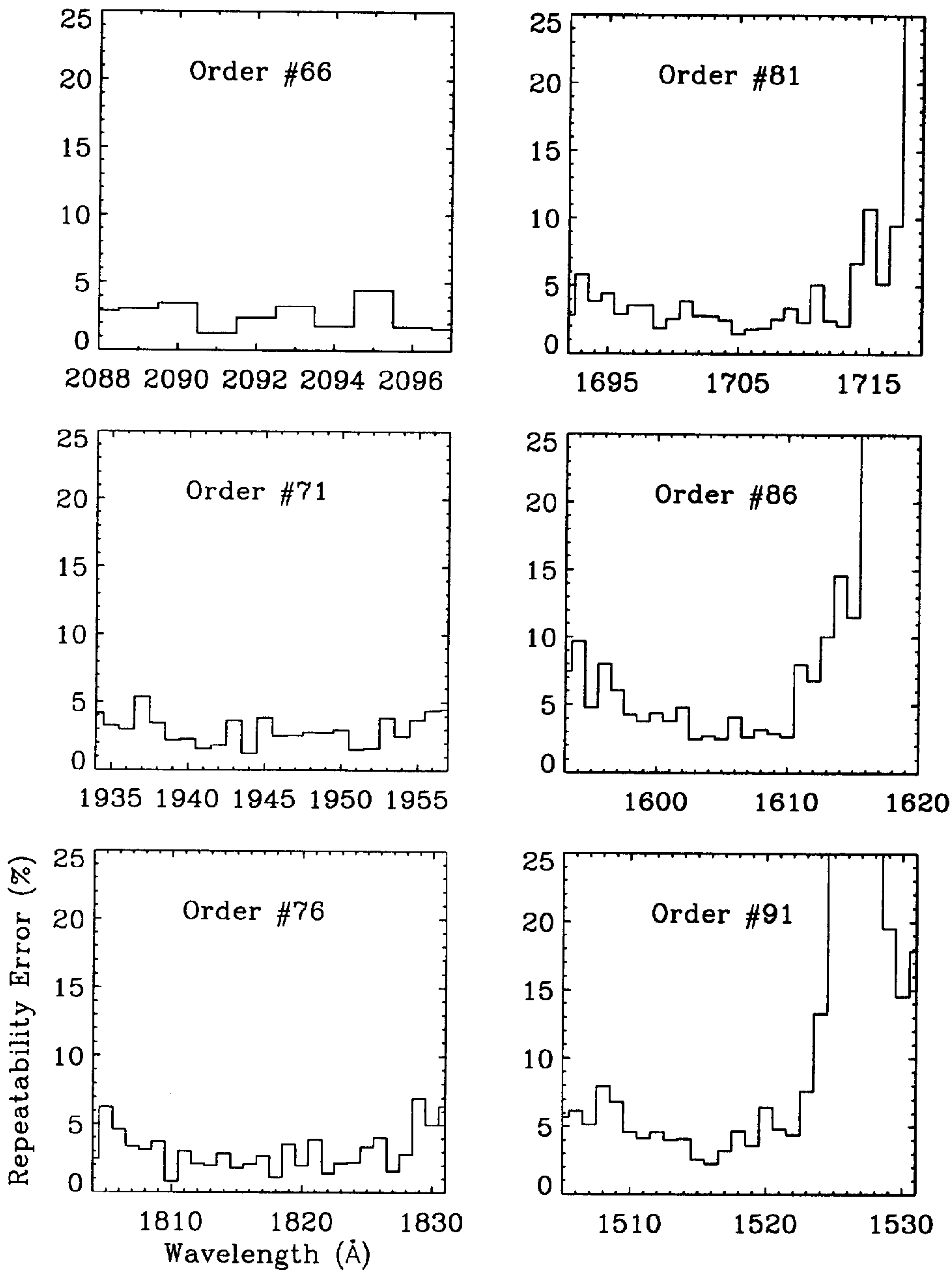

Figure 5: SWP high-dispersion repeatability as a function of wavelength for 80% exposures.

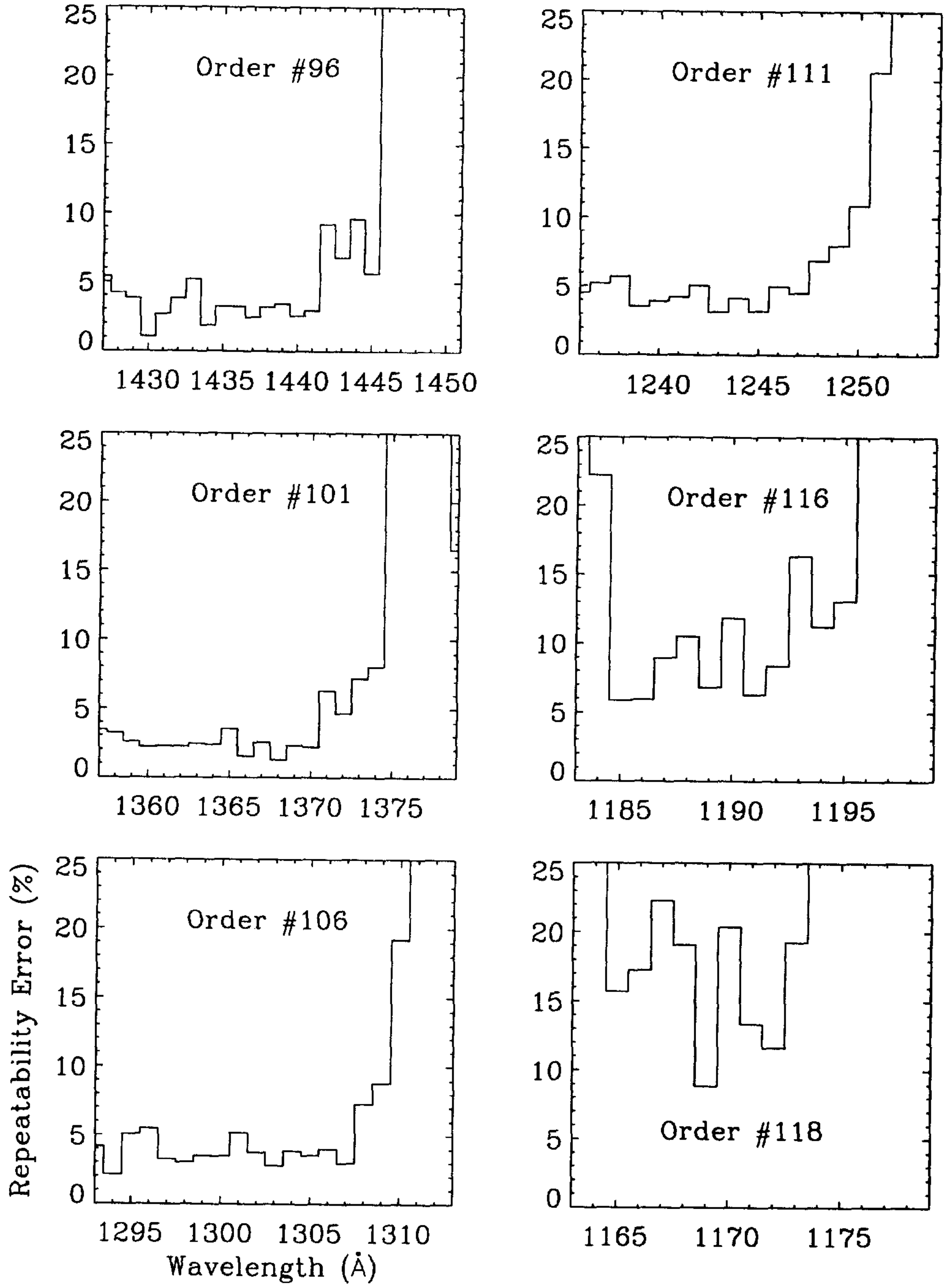

Figure 6: SWP high-dispersion repeatability as a function of wavelength for 80% exposures.

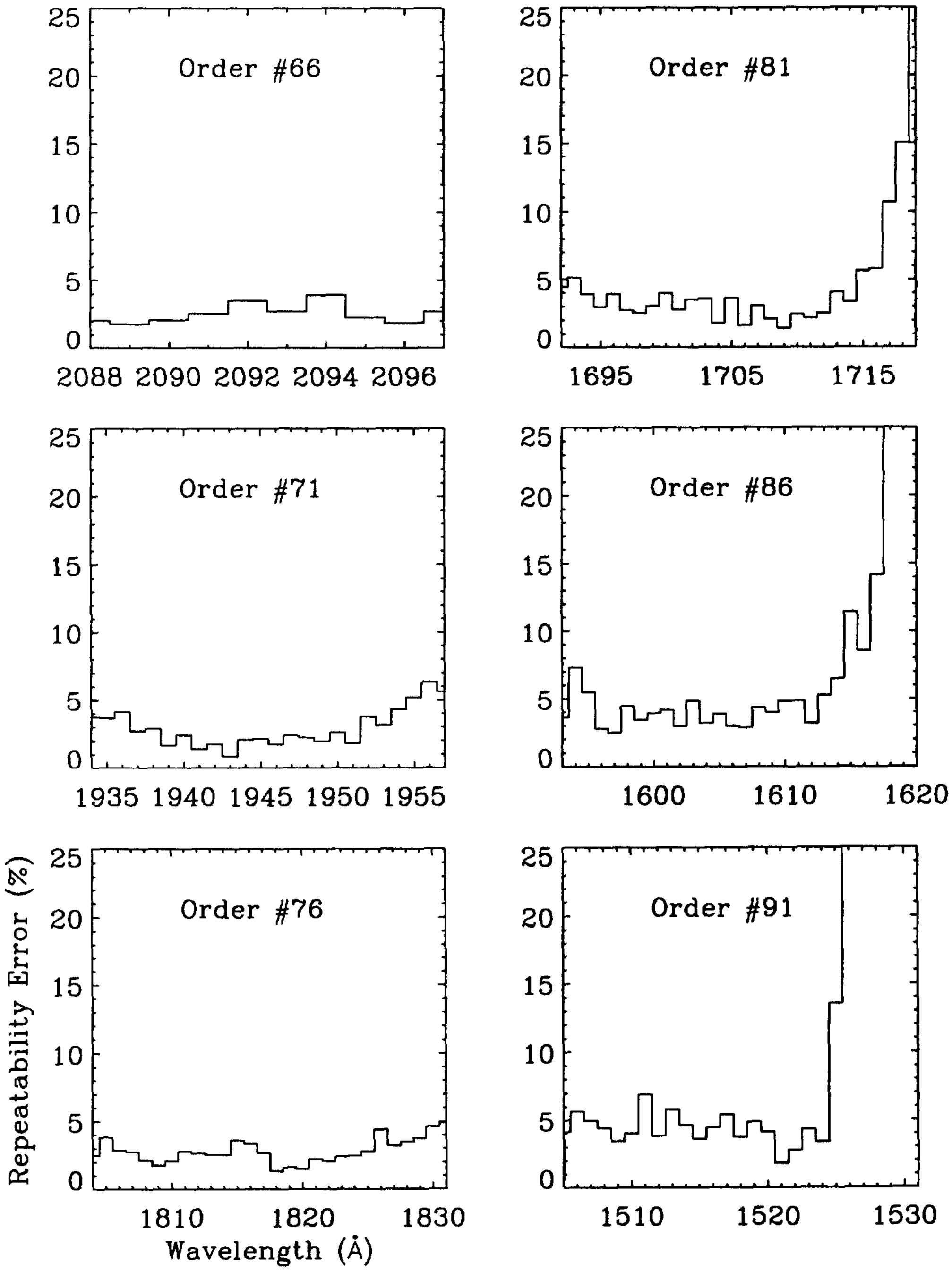

Figure 7: SWP high-dispersion repeatability as a function of wavelength for 100% exposures.

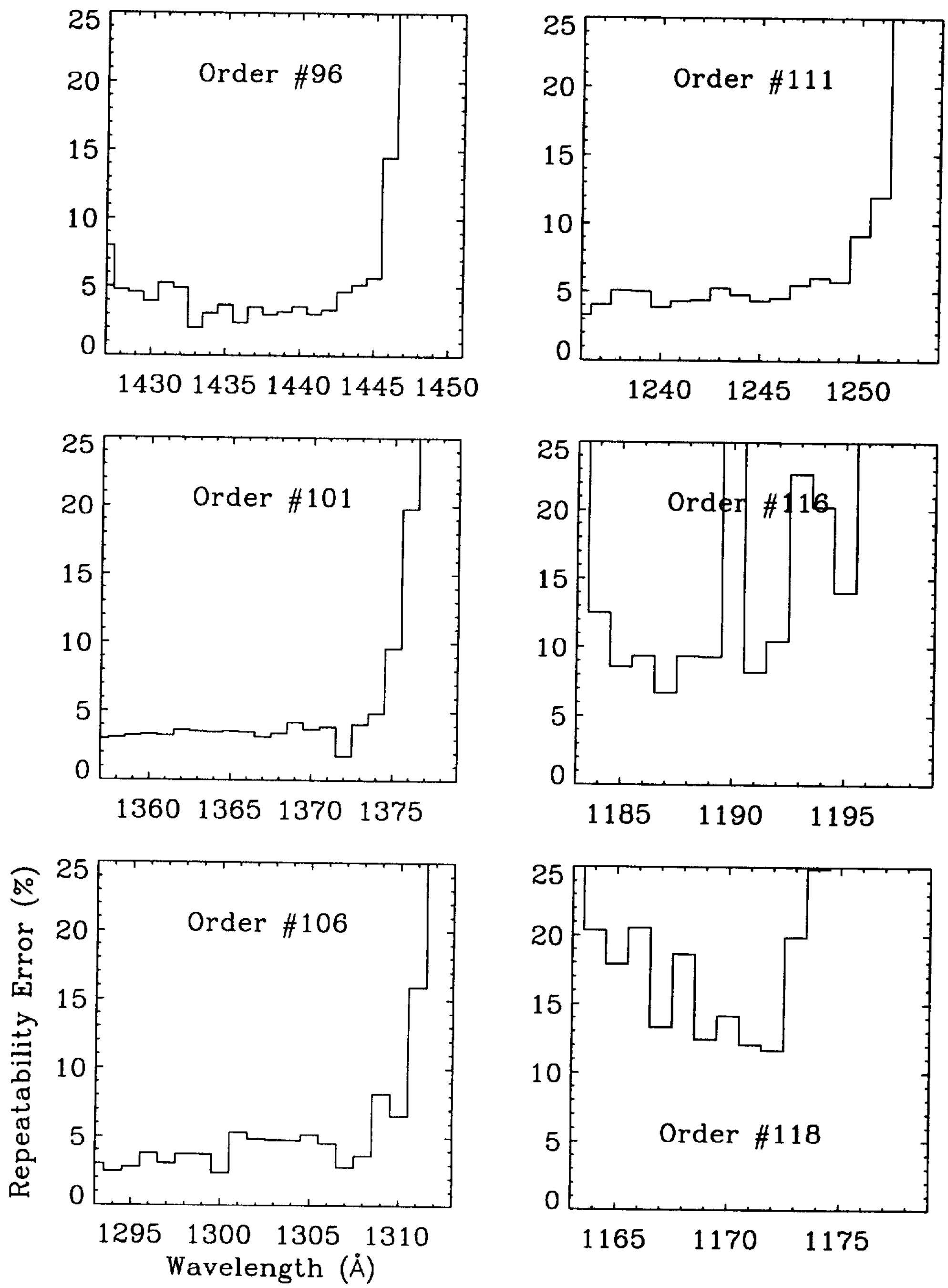

Figure 8: SWP high-dispersion repeatability as a function of wavelength for 100% exposures.

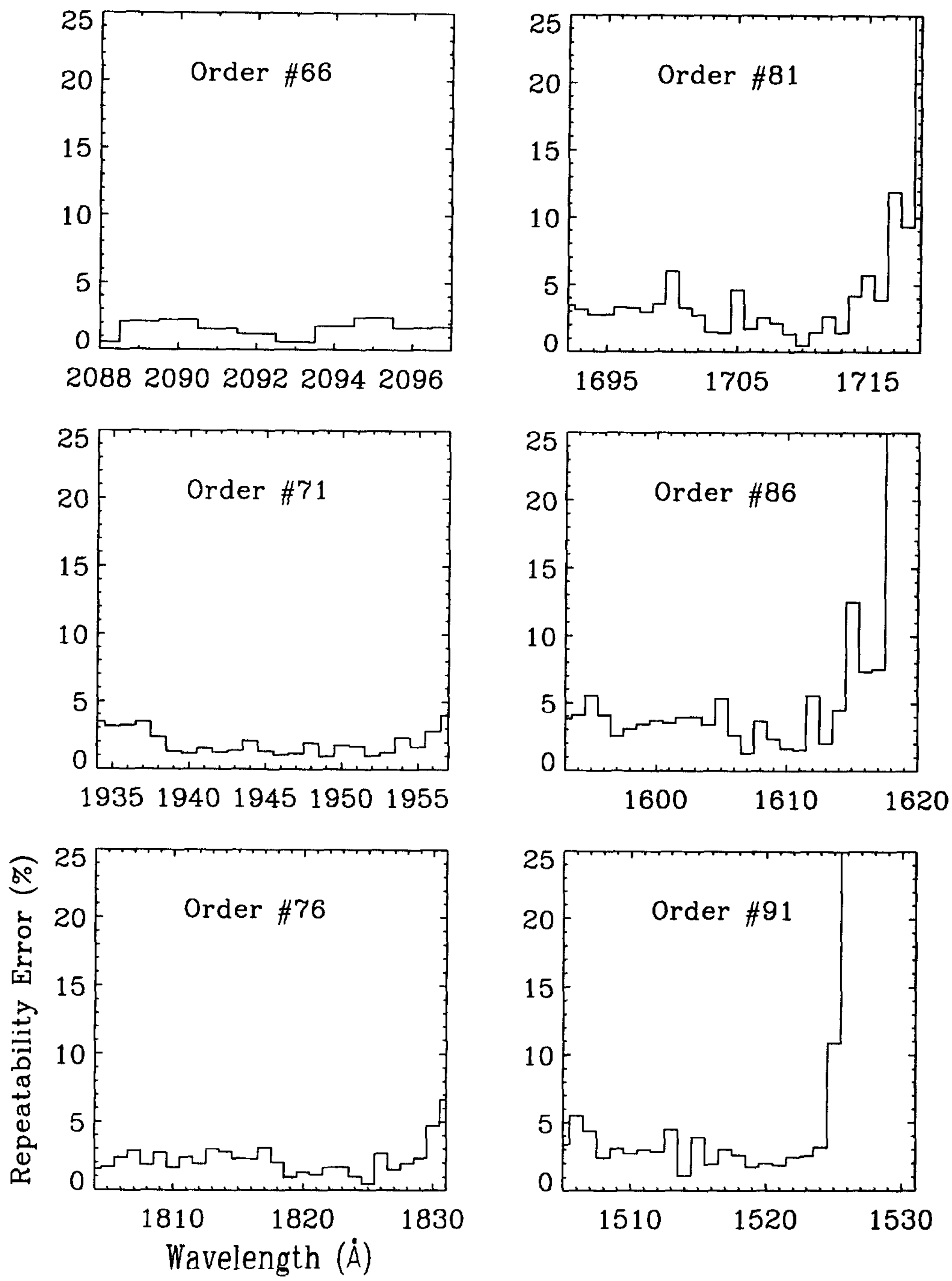

Figure 9: SWP high–dispersion repeatability as a function of wavelength for 2 coadded exposures.

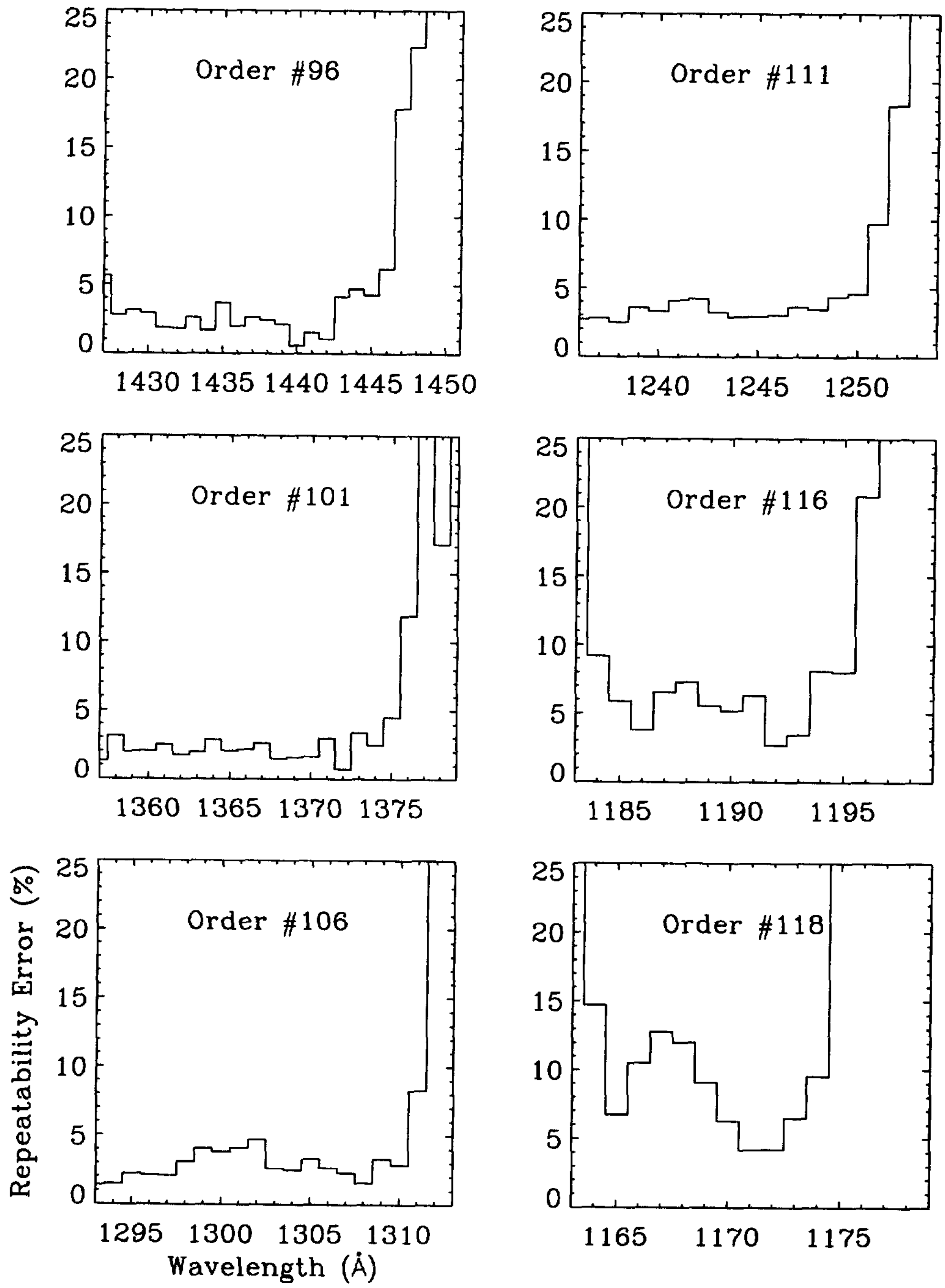

Figure 10: SWP high-dispersion repeatability as a function of wavelength for 2 coadded exposures.

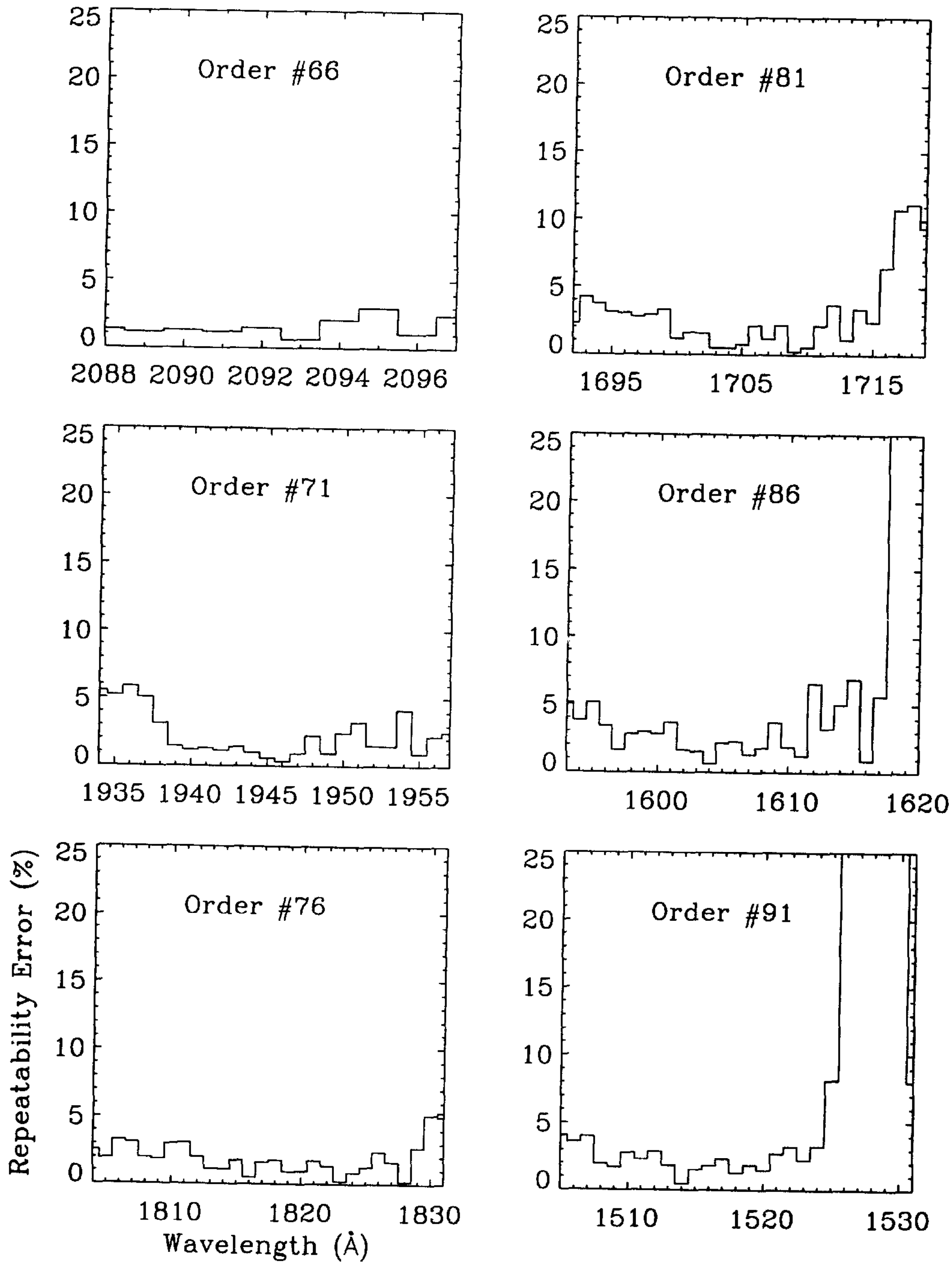

Figure 11: SWP high-dispersion repeatability as a function of wavelength for 3 coadded exposures.

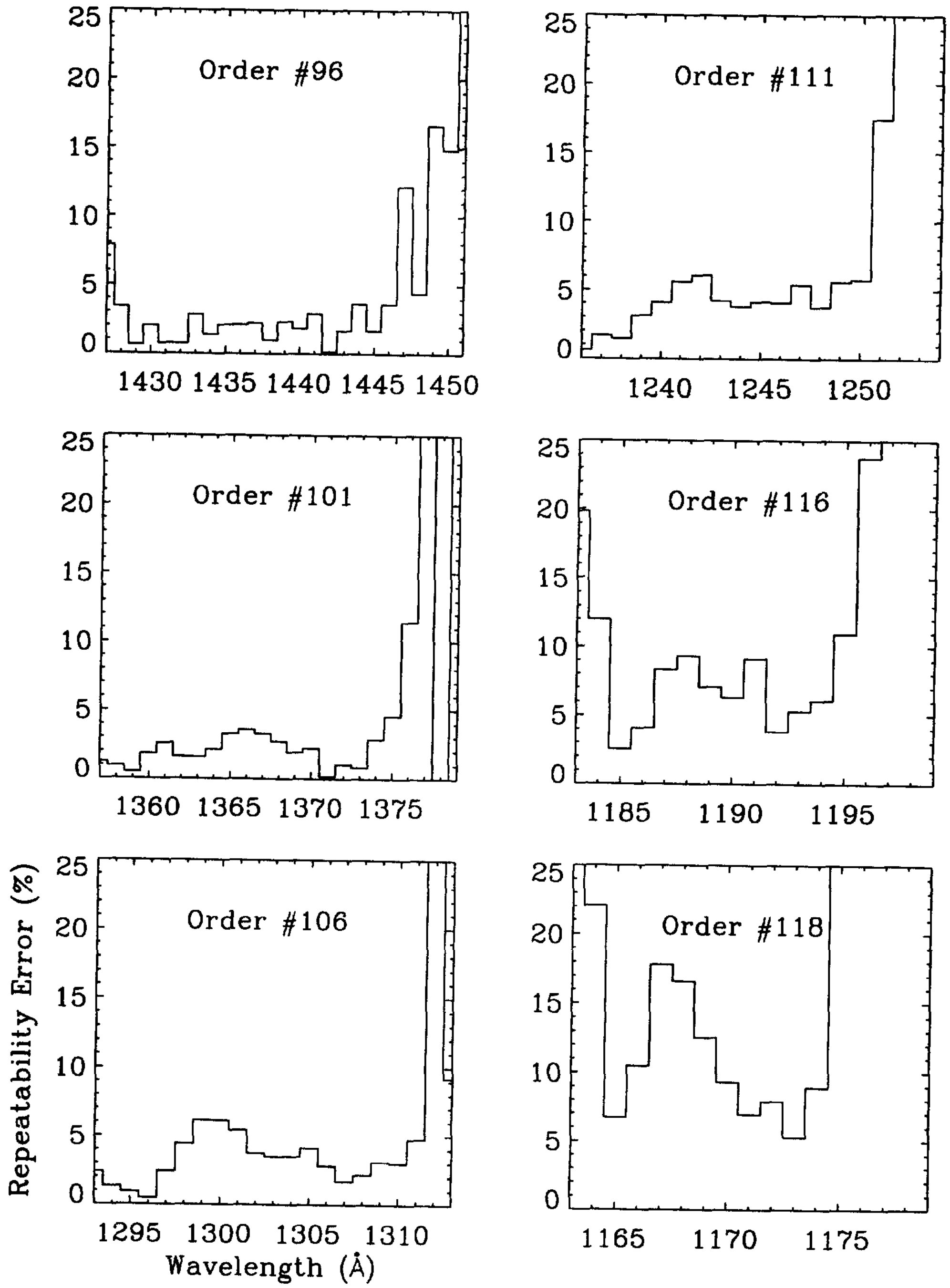

Figure 12: SWP high-dispersion repeatability as a function of wavelength for 3 coadded exposures.

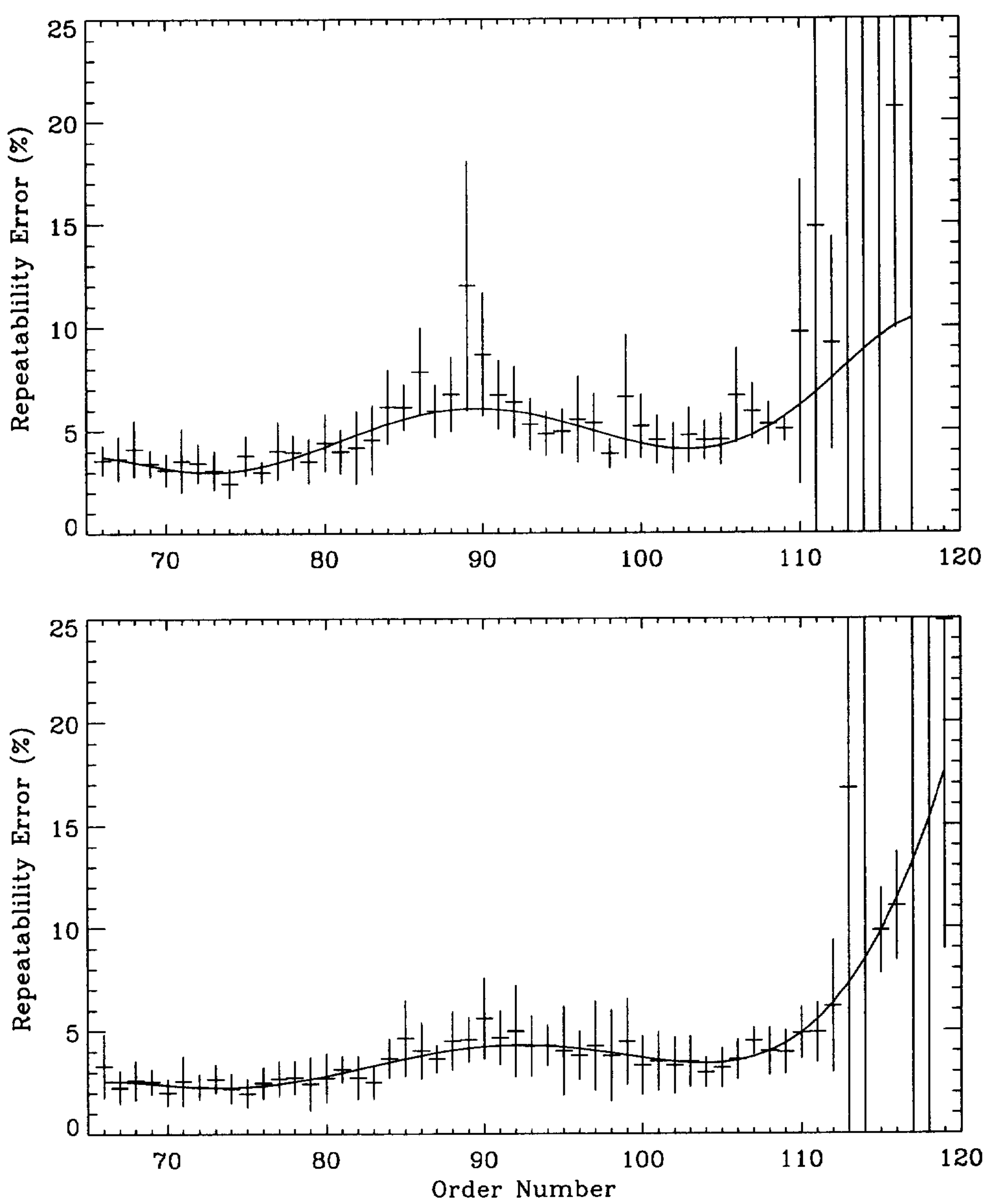

Figure 13: Average SWP high−dispersion repeatability as a function of order number for 40% (top) and 60% (bottom) exposure levels fitted with a sixth−order polynomial.

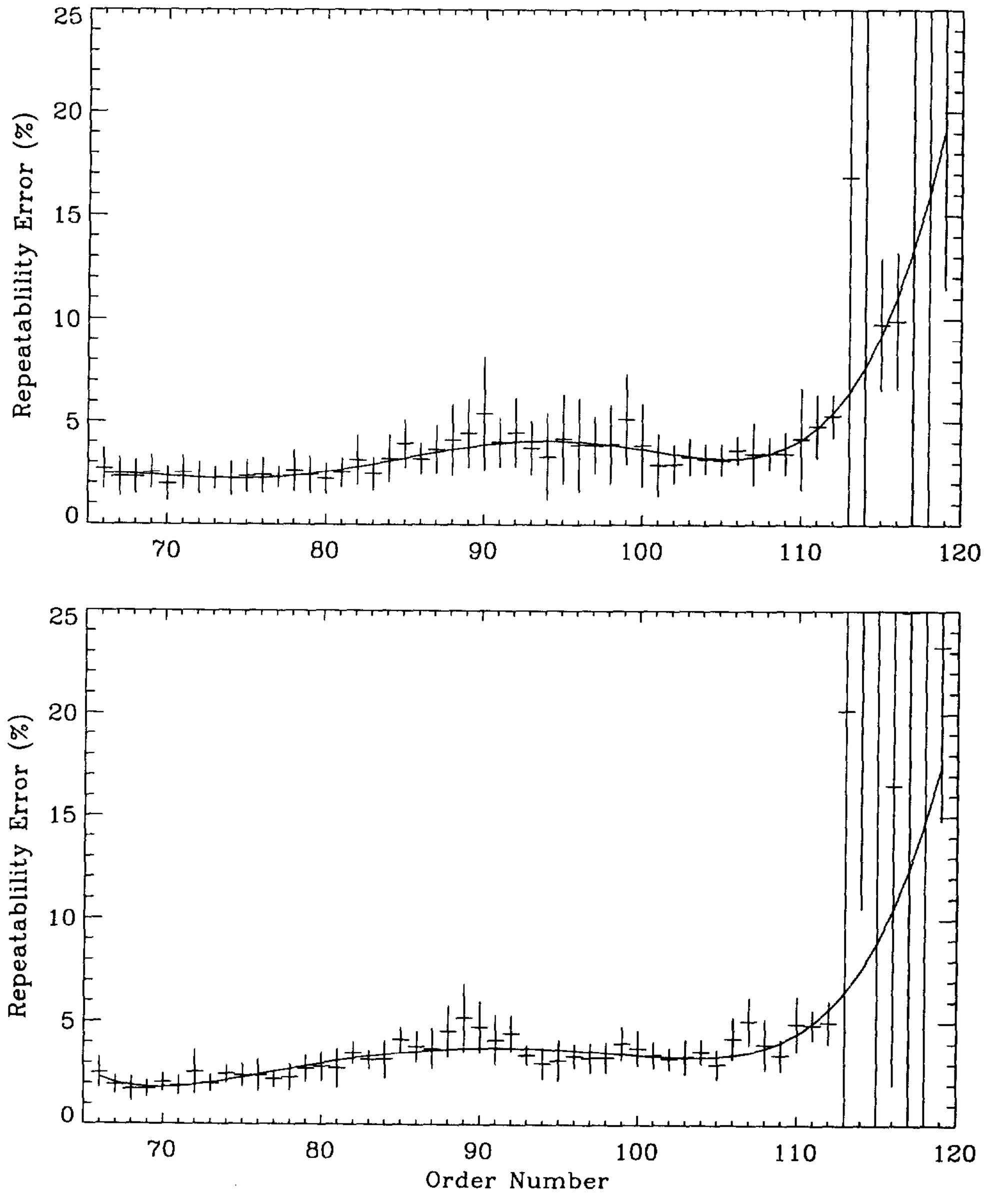

Figure 14: Average SWP high-dispersion repeatability as a function of order number for 80% (top) and 100% (bottom) exposure levels fitted with a sixth-order polynomial.

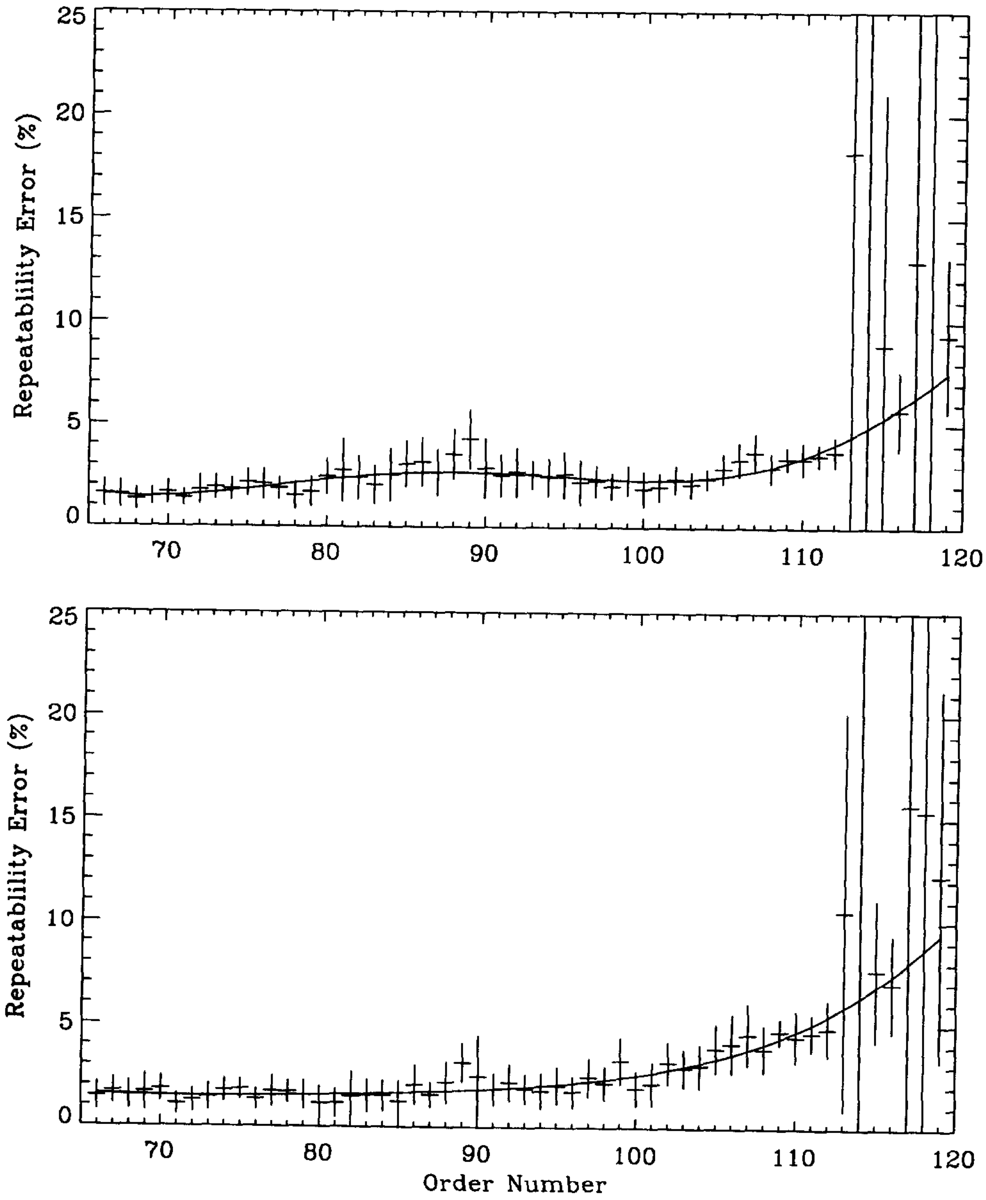

Figure 15: Average SWP high-dispersion repeatability as a function of order number for 2 coadded (top) and 3 coadded (bottom) exposures fitted with a sixth-order polynomial.