New Dispersion Relations for IUESIPS

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Abstract

The mean dispersion constants and the time and temperature dependent correlation coefficients have been updated for current IUESIPS using data taken prior to April 1993 and were implemented at GSFC and VILSPA on June 10, 1993. The last update to the dispersion relations, as used in production processing, was April 1988 at GSFC (Thompson 1988). The previous update to the dispersion constants (Garhart 1991) was not implemented due to technical problems in porting it to the VILSPA Telefile system, which is similar to the old Sigma 9 used at GSFC. VILSPA has converted their IUESIPS processing software to the VAX, so that both stations were able to implement the updated wavelength calibration. The estimated error in wavelength assignments for 1993 data as a result of using the outdated coefficients can be summarized as follows. The SWP camera shows shifts of approximately 16 km/s along the spectral orders in high-dispersion and around 1.5 Å in low. The errors along the orders in the LWR are around 5.5 km/s for high-dispersion and 1.5 Å in low-dispersion. The errors in the LWP data have not been determined as the time dependent variations are small. Spectral motions perpendicular to the dispersion are of no consequence as they are compensated for during image processing.

Introduction

Wavelength calibration (WAVECAL) images are obtained once a month using Platinum-Neon (Pt-Ne) calibration lamps. Each set of WAVECAL images is used to determine the relationship between wavelength and the line and sample position of a pixel on the camera. WAVECAL images are a combination of the Pt-Ne spectrum and a Tungsten flood-lamp (TFLOOD) exposure that is used to illuminate the reseau marks needed to perform the geometric correction on the raw WAVECAL images. Since approximately mid-1992, however, WAVECAL images have been obtained without the superimposed TFLOOD exposure as it was found that the NEWSIPS wavelength calibration analysis works better without it. Instead, the TFLOOD is now taken as a separate exposure. The reseau marks are found on the low-dispersion WAVECAL (or TFLOOD) image using a cross-correlation technique and a reseau displacement grid, which compensates for geometric distortions, is constructed and applied to both the low- and high-dispersion WAVECAL images.

The location of several emission lines, whose starting positions are determined from a set of mean dispersion constants, are found using a cross-correlation technique and combined with the laboratory measured order and wavelength position for each line. A regression analysis routine is then used to determine the dispersion relation, which equates the line and sample positions of any pixel given a wavelength and order number, for a particular WAVECAL image. The dispersion relations for line and sample positions are calculated by the following expressions:

$$L = B_1 + B_2 m\lambda + B_3 (m\lambda)^2 + B_4 m + B_5 \lambda + B_6 m^2 \lambda + B_7 m \lambda^2 \tag{0.1}$$

$$S = A_1 + A_2 m\lambda + A_3 (m\lambda)^2 + A_4 m + A_5 \lambda + A_6 m^2 \lambda + A_7 m \lambda^2 \tag{0.2}$$

where m is the order number and λ is the wavelength in angstroms. For low-dispersion, m equals one and only the first two terms are used. The dispersion constants derived from each individual WAVECAL image are entered into a master dispersion constant file which is periodically analyzed to determine if updates to the mean dispersion constants should be made. The mean dispersion constants, as implemented in production processing, are produced by averaging together the individual terms contained in the master files. The rationale behind implementing mean dispersion constants is to eliminate discontinuities in the way *IUE* data are reduced by avoiding the risk of using an atypical set of constants which may differ due to unusual thermal conditions occuring at the time the WAVECAL exposure was taken (Turnrose, Bohlin, and Harvel 1979 and Thompson, Turnrose, and Bohlin 1981).

Spectral format shifts as a function of time and camera head amplifier temperature (THDA) are seen in the LWR and SWP cameras (the LWP camera only uses a thermal correction). These format shifts are compensated for by using a set of time and temperature dependent correlation coefficients which are determined by using a Gauss-Jordan matrix elimination technique and are added to the zeroeth-order term of the dispersion relations using the following equations:

$$W_L = W_{L1} + W_{L2} T + W_{L3} t + W_{L4} t^2 \tag{0.3}$$

$$W_S = W_{S1} + W_{S2} T + W_{S3} t + W_{S4} t^2 \tag{0.4}$$

where T is the THDA at the time of the exposure and t is the time in days since January 1, 1978 (only the first two terms are used for the LWP). A more detailed description of the WAVECAL process can be found in the *IUE* Image Processing Manual (Turnrose and Thompson 1984).

Implementation of New Dispersion Relations

New dispersion constants and time and temperature dependent coefficients have been determined for all three cameras. The previous set of dispersion constants and coefficients were derived using WAVECAL data obtained prior to September 1987 (Thompson 1988). This new analysis is generated from WAVECALS taken prior to April 1993 and does not include the updated line library (Bushouse 1991) or the new form of the dispersion relation (Smith 1990). These issues will be addressed only in the Final Archive (NEWSIPS) software.

The figures in Table 1 show various statistics concerning the master dispersion constant database and the standard deviations before and after the time and temperature corrections are applied. The new mean dispersion constants and correlation coefficients are listed in Table 2 and are used in Equations 1 through 4 to determine the line and sample positions of pixels in geometrically-corrected space. A comparison of various combinations of time and/or temperature fits are displayed in Table 3. One sees that by using the combination of a temperature and second-order time correlation for the LWR and SWP data substantially reduces the RMS errors when compared with other types of fits, however, there is less of an improvement over using this type of fit for the LWP camera versus using a simple temperature dependent fit. Spectral motion along the dispersion due to this time dependent effect amounts to 0.11 pixels/year in high-dispersion and -0.03 pixels/year in low-dispersion. The calibration group feels that it would be a wasted effort in trying to switch over to a first-order time and THDA dependent fit at this late a period of time (the NEWSIPS wavelength calibration uses this type of fit in its analysis).

Systematic wavelength errors, which increase with time, can occur as a result of using outdated correlation coefficients. The plots in Figures 1 through 12 show the high- and low-dispersion WAVECAL data fitted using both the old and new set of correlation coefficients. The 'x' symbols, in each case, represent the raw scatter about the mean in the position of a single wavelength assignment as a function of time. The values are generated by calculating line and sample positions using each individual set of dispersion constants in the master dispersion constant file, converting them to positions perpendicular and along the dispersion, and subtracting the mean. The scatter seen in the data is also a good example of why mean dispersion constants are used. The use of dispersion constants derived from individual WAVECALS would introduce serious discontinuities in the determination of line and sample positions for a given pixel from month to month. The '+' symbols, connected by a jagged line, represent the data after applying a first-order THDA dependent correction. The curved line represents the correction made by applying a second-order time dependent fit to the temperature corrected data (the LWP uses a first-order time fit). Any deviation of the smooth line from the jagged one represents an error in the correction that was applied, as one would expect from using an outmoded set of correlation coefficients.

The errors that occur from using the previous set of coefficients are not very noticeable in the LWP data (Figures 1 and 3) since the time dependent variations are small. The LWR and SWP data (Figures 5, 7, 9, and 11) exhibit more pronounced time dependent deviations starting around 1988 (*i.e.* about the time the previous set of correlation coefficients were implemented). The errors introduced to LWR data taken in 1993 as a result of using the outdated correction coefficients amount to a shift of less than one pixel along the dispersion (spectral direction) in both high- and low-dispersion. This corresponds to a wavelength error of about 1.5Å for low-dispersion data and around 5.5 km/s for high-dispersion data. The SWP errors along the dispersion for 1993 data result in a shift of around two pixels or approximately 16 km/s in high-dispersion, while low-dispersion shifts result in an error of approximately one pixel or 1.5Å. Spectral motions perpendicular to the dispersion are inconsequential as these shifts are compensated for during the spectral registration process, while spectral motion along the dispersion direction results in a wavelength error.

One drawback in using a second-order fit for the time dependent spectral motion is evident in the LWR and SWP plots (Figures 6, 8, 10, and 12). It appears that this time dependency is slowly flattening out (*i.e.* these two cameras are finally stabilizing). Unfortunately, the second-order fit is turning over (since it is a paraboloid). As is the case with the LWP analysis, the calibration group decided not to update the time dependent spectral motion to a third-order fit as this would involve a major change to the IUESIPS software, in addition to the fact that NEWSIPS processing has already begun (NEWSIPS wavelength calibration analysis uses a third-order time dependent fit). The errors associated with this problem are very small (less than 0.5 pixels for 1993 data).

Figures 13 through 15 show the difference in calculated pixel positions for each wavelength in the line library using the old and new mean dispersion constants. The diamond shaped symbols represent locations from the old set of means and the lines point towards the shifted locations determined from the new set of mean dispersion constants. These spectral motions are due mostly to the time dependent shifts and are independent of wavelength and dispersion (Thompson 1988).

A test of the accuracy of this new wavelength calibration was performed yielding mixed results. The central wavelengths of several interstellar absorption features were measured using a gaussian fitting routine and compared with their known rest wavelengths. Low-dispersion data showed excellent results, with residual errors (*i.e.* errors not removed by the updated dispersion constants and correlation coefficients) on the order of less than 0.2Å. High-dispersion data taken in 1993, however, showed larger residuals than expected. These residuals are typically on the order of ~25 km/s for the LWP, ~20 km/s for the LWR, and ~10 km/s for the SWP. The cause of these errors is unkown at this time. See Mansperger (1992) for a more detailed analysis of this problem.

Software is available through the *IUE* Data Analysis Center (IUEDAC) that allows the user to correct wavelengths for low- or high-dispersion LWR and SWP images taken after 1984 which were processed using the outdated dispersion constants. The procedure is called DCCOR and resides in the experimental library.

References

Bushouse, H. 1991, IUE NASA Newsletter, No. 45, 46

Garhart, M. 1991, IUE NASA Newsletter, No. 46, 31

Mansperger, C. 1992, IUE NASA Newsletter, No. 49, 31

Smith, M. 1990, *Record of the IUE Three-Agency Coordination Committee*, March 1990, p. B-51

Thompson, R. 1988, IUE NASA Newsletter, No. 35, 108

Thompson, R., Turnrose, B., and Bohlin, R. 1981, IUE NASA Newsletter, No. 15, 8

Turnrose, B., Bohlin, R., and Harvel, C. 1979, IUE NASA Newsletter, No. 7, 17

Turnrose, B., and Thompson, R. 1984, *IUE* Image Processing Information Manual, Version 2.0 (New Software), CSC/TM-84/6058

Table 1.

Dispersion Constant Statistics

Low Dispersion

	LWP	**LWR**	**SWP**
No. of D.C.	195	193	250
Mean Time	1986.72	1984.56	1985.24
Start Time	1980.46	1978.54	1978.75
End Time	1993.16	1992.92	1993.16
Mean THDA (°C)	9.4	13.3	9.1
Min. THDA	5.5	8.8	4.8
Max. THDA	13.8	18.3	13.2
Raw Scatter (in pixels)			
Parallel	0.44	0.38	1.09
Perpendicular	0.76	1.80	1.15
Scatter after correction	[THDA only]	[THDA & $Time^2$]	[THDA & $Time^2$]
Parallel	0.33	0.29	0.23
Perpendicular	0.42	0.42	0.37

High Dispersion

	LWP	**LWR**	**SWP**
No. of D.C.	193	191	251
Mean Time	1986.73	1984.63	1985.21
Start Time	1980.46	1978.75	1978.70
End Time	1993.16	1992.92	1993.16
Mean THDA (°C)	9.7	13.7	9.2
Min. THDA	6.2	9.5	5.1
Max. THDA	14.2	18.3	13.2
Raw Scatter (in pixels)			
Parallel	0.78	1.51	1.24
Perpendicular	0.40	0.30	0.60
Scatter after correction	[THDA only]	[THDA & $Time^2$]	[THDA & $Time^2$]
Parallel	0.36	0.39	0.29
Perpendicular	0.21	0.23	0.17

Table 2.

Mean Dispersion Constants and Correlation Coefficients
For the Small Aperture (1 of 3)

Dispersion Constants	**LWP Low**	**LWP High**
$A_1 =$	0.1046990495384615D+04	0.4449383035958549D+04
$A_2 =$	-.2868118326153846D+00	-.1612708465803109D+00
$A_3 =$		0.6345493010051814D-06
$A_4 =$		0.1749598398341969D+02
$A_5 =$		0.4220819182901554D+00
$A_6 =$		-.7540104282438860D-04
$A_7 =$		-.3055269914911917D-05
$B_1 =$	-.2717110705128205D+03	0.1562766122217617D+04
$B_2 =$	0.2464409074871795D+00	-.1511533097150259D+00
$B_3 =$		0.6204505735803108D-06
$B_4 =$		0.2468743562756477D+00
$B_5 =$		0.3078674554404145D+00
$B_6 =$		-.9891299943005182D-06
$B_7 =$		-.2657798041606218D-06

Correlation Coefficients

$W_{S1} =$	-.1103539629405574D+01	-.1099706323776034D+01
$W_{S2} =$	0.1168639655995736D+00	0.1134472031827129D+00
$W_{L1} =$	-.3858055944928537D+01	-.4700774618462976D+01
$W_{L2} =$	0.4085650439868866D+00	0.4849383164641394D+00

Table 2.

Mean Dispersion Constants and Correlation Coefficients
For the Small Aperture (2 of 3)

Dispersion Constants	**LWR Low**	**LWR High**
$A_1 =$	-.3000062512435233D+03	-.4474930255652356D+04
$A_2 =$	0.3022976560621762D+00	0.1437455140314136D+00
$A_3 =$		-.5445030597853403D-06
$A_4 =$		0.3573461270785340D-01
$A_5 =$		0.2829606246073298D+00
$A_6 =$		-.9437298575916230D-07
$A_7 =$		0.8524766965968586D-07
$B_1 =$	-.2640785015544041D+03	0.1558470682722513D+05
$B_2 =$	0.2257140275129534D+00	-.2789873294764398D+00
$B_3 =$		0.9111058581832461D-06
$B_4 =$		0.5694243220994765D-01
$B_5 =$		0.2257196829319372D+00
$B_6 =$		0.6435034952879581D-08
$B_7 =$		0.6166729439790576D-08

Correlation Coefficients

$W_{S1} =$	0.5989002152442644D+01	0.6027901355921964D+01
$W_{S2} =$	-.2489574596652185D+00	-.3033352329649220D+00
$W_{S3} =$	-.1853757884056476D-02	-.1334874547580696D-02
$W_{S4} =$	0.2249311497099524D-06	0.1700568517347630D-06
$W_{L1} =$	-.9319488395873679D+01	-.9206285932124056D+01
$W_{L2} =$	0.4983012916739970D+00	0.5509789739185724D+00
$W_{L3} =$	0.1875956730975977D-02	0.1124341083483957D-02
$W_{L4} =$	-.2303205745240299D-06	-.1319321801506303D-06

Table 2.

Mean Dispersion Constants and Correlation Coefficients
For the Small Aperture (3 of 3)

Dispersion Constants	**SWP Low**	**SWP High**
$A_1 =$	0.9849297490400000D+03	-.3296764496215140D+03
$A_2 =$	-.4666908635999999D+00	-.1588703715219123D+00
$A_3 =$		0.1225612983585657D-05
$A_4 =$		0.1389334744378486D+00
$A_5 =$		-.4401700844621514D+00
$A_6 =$		-.9992204517211155D-06
$A_7 =$		-.1960928604223108D-06
$B_1 =$	-.2630196944400000D+03	-.7434765340637451D+04
$B_2 =$	0.3761291330400000D+00	-.1141566982513944D+00
$B_3 =$		0.1207281965776892D-05
$B_4 =$		-.8885825901912351D-01
$B_5 =$		0.3929990657250996D+00
$B_6 =$		0.6514668413067729D-06
$B_7 =$		-.1319679762988048D-06

Correlation Coefficients

$W_{S1} =$	-.4113283229177548D+01	-.3541515672783277D+01
$W_{S2} =$	-.1158026083776323D-01	0.5927306543829729D-01
$W_{S3} =$	0.2564865714534697D-02	0.1767013094572669D-02
$W_{S4} =$	-.2845990490456551D-06	-.1849919824149710D-06
$W_{L1} =$	-.1775029890855584D+01	-.3345419871310001D+01
$W_{L2} =$	0.1475653545821624D+00	0.2307490346596490D+00
$W_{L3} =$	0.3613545330344427D-03	0.7516121415382416D-03
$W_{L4} =$	-.5778680508331149D-07	-.8460501848187051D-07

Table 3.

Total RMS Scatter (in pixels) for Various Corrections to the Mean Dispersion Constants

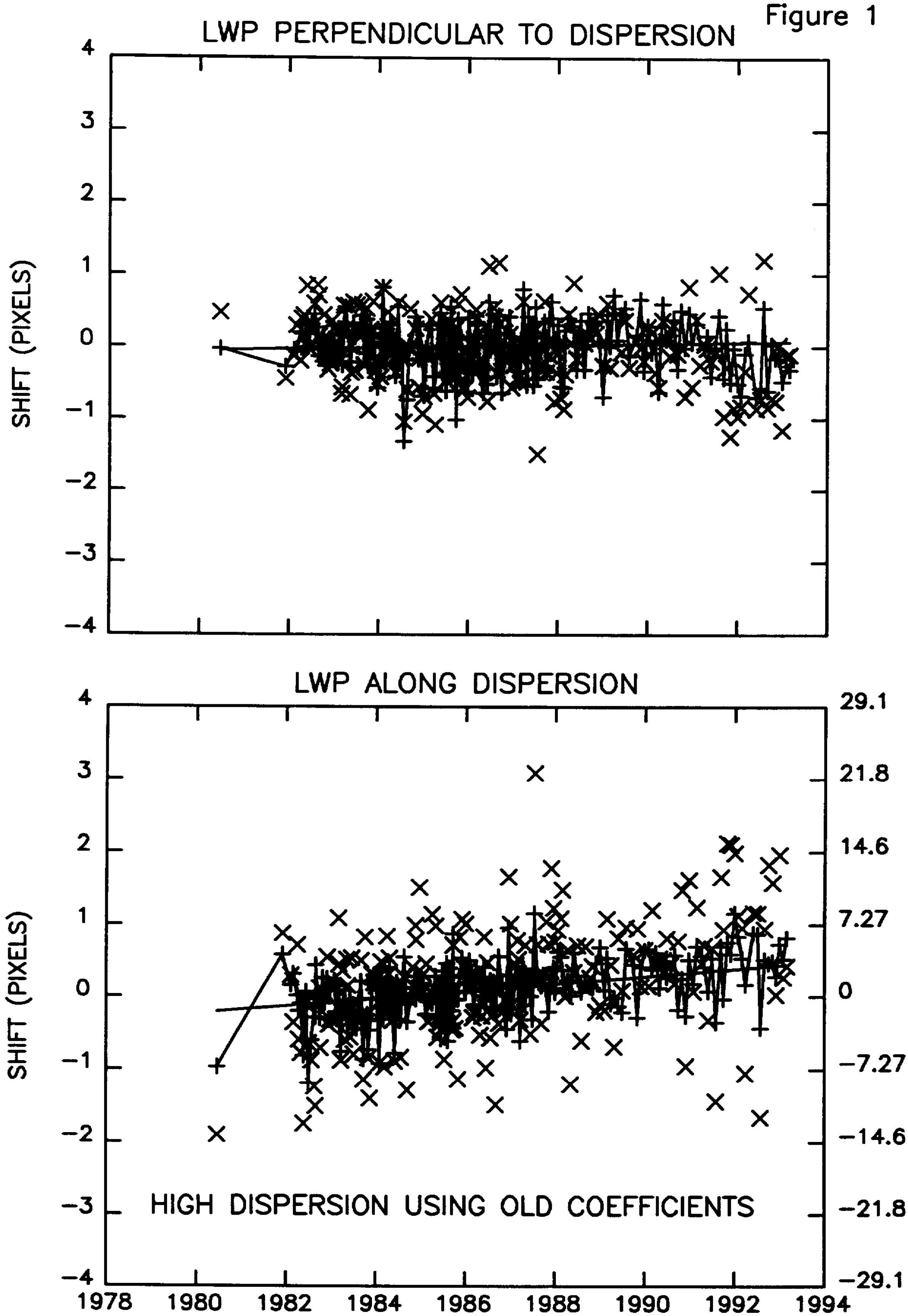
Low Dispersion

	LWP	LWR	SWP
Raw Scatter	0.88	1.84	1.59
1st Order Time	0.78	1.24	0.78
1st Order THDA	0.53	1.53	1.50
THDA and 1st Order Time	0.45	0.80	0.73
THDA and 2nd Order Time	0.44	0.51	0.44
No. of Points	195	193	250

High Dispersion

	LWP	LWR	SWP
Raw Scatter	0.88	1.54	1.38
1st Order Time	0.83	1.19	0.69
1st Order THDA	0.41	1.02	1.17
THDA and 1st Order Time	0.39	0.61	0.54
THDA and 2nd Order Time	0.39	0.45	0.34
No. of Points	193	191	251

Figure 1



LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 2

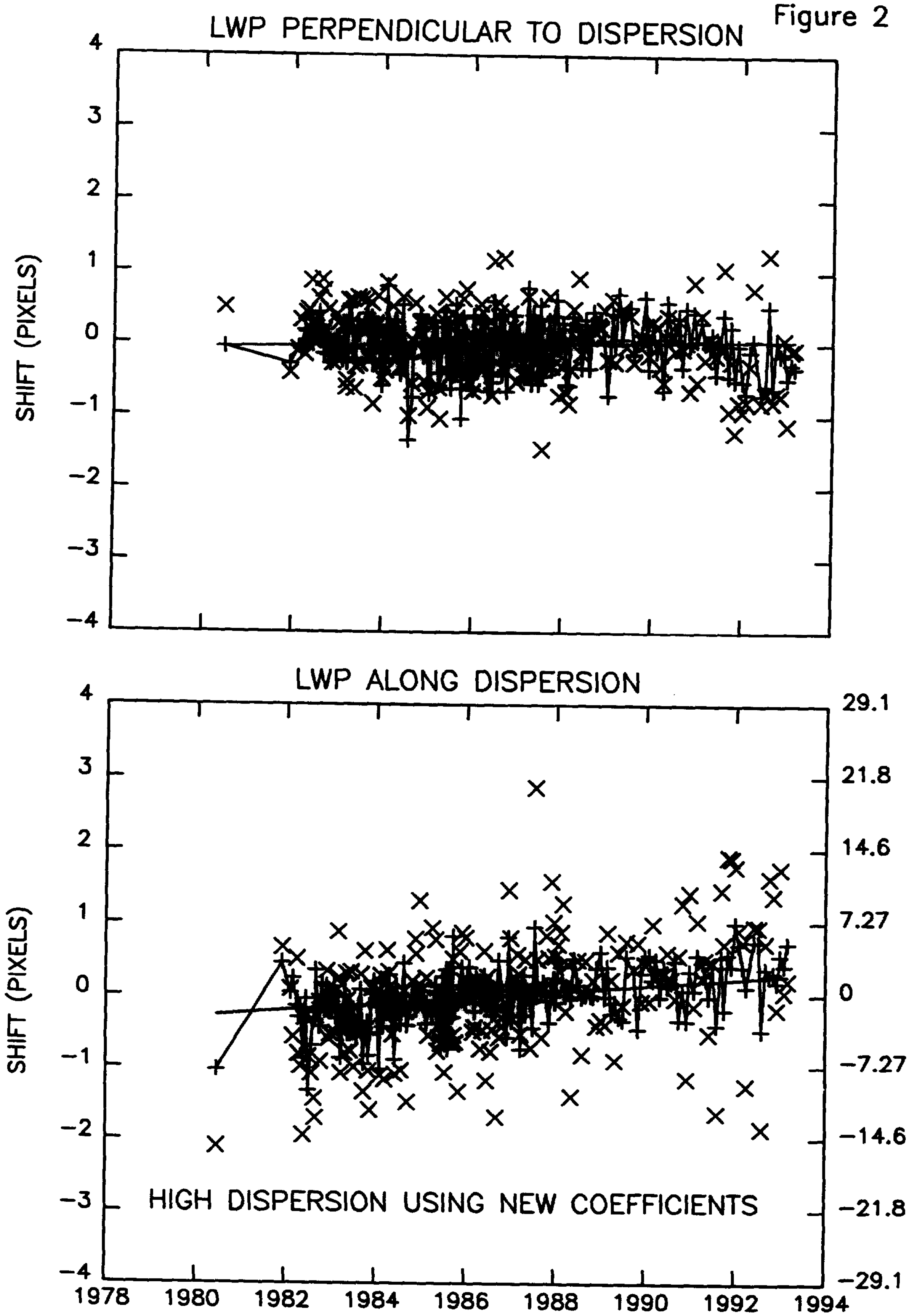
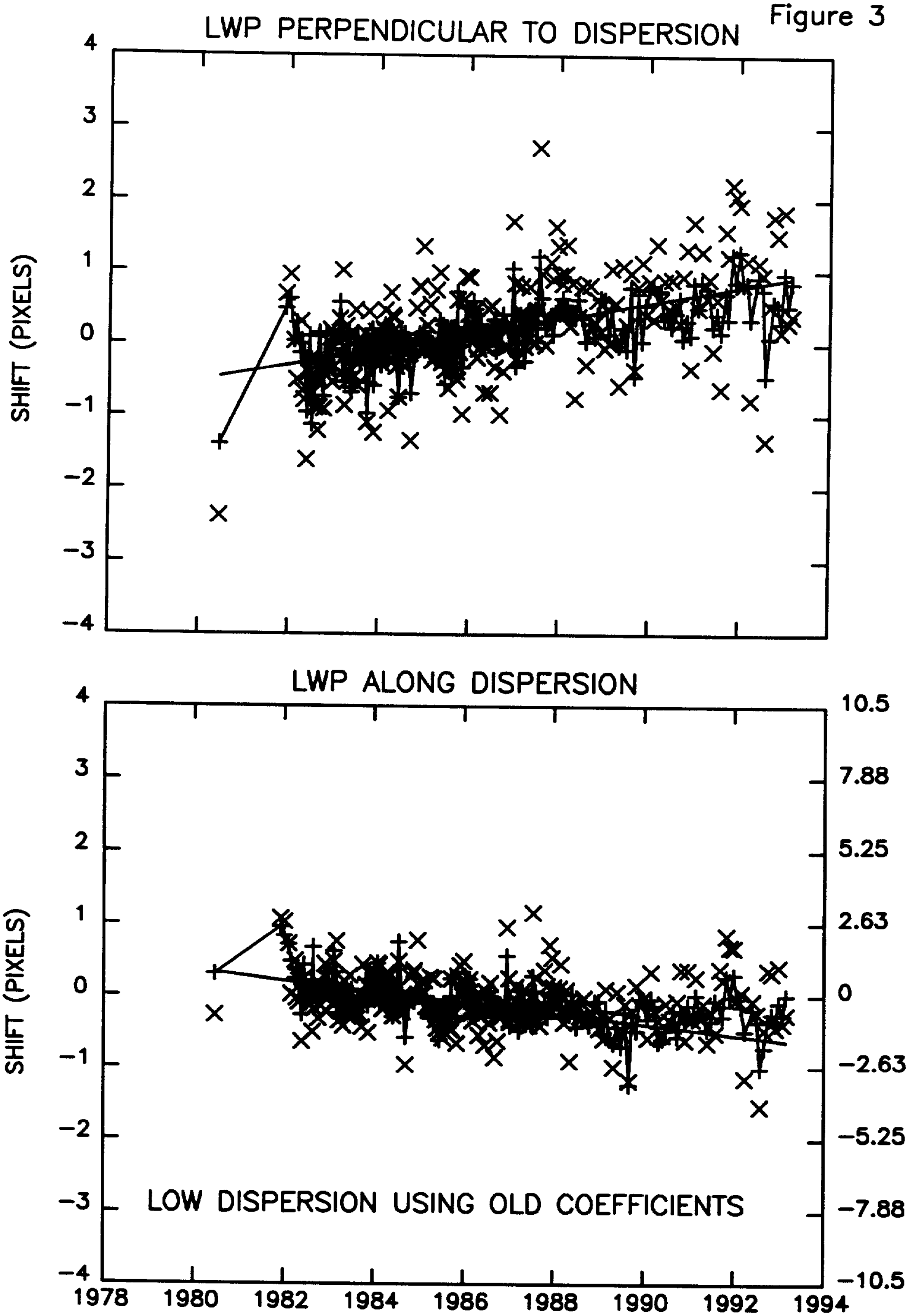

LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
HIGH DISPERSION USING NEW COEFFICIENTS
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 3



LWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
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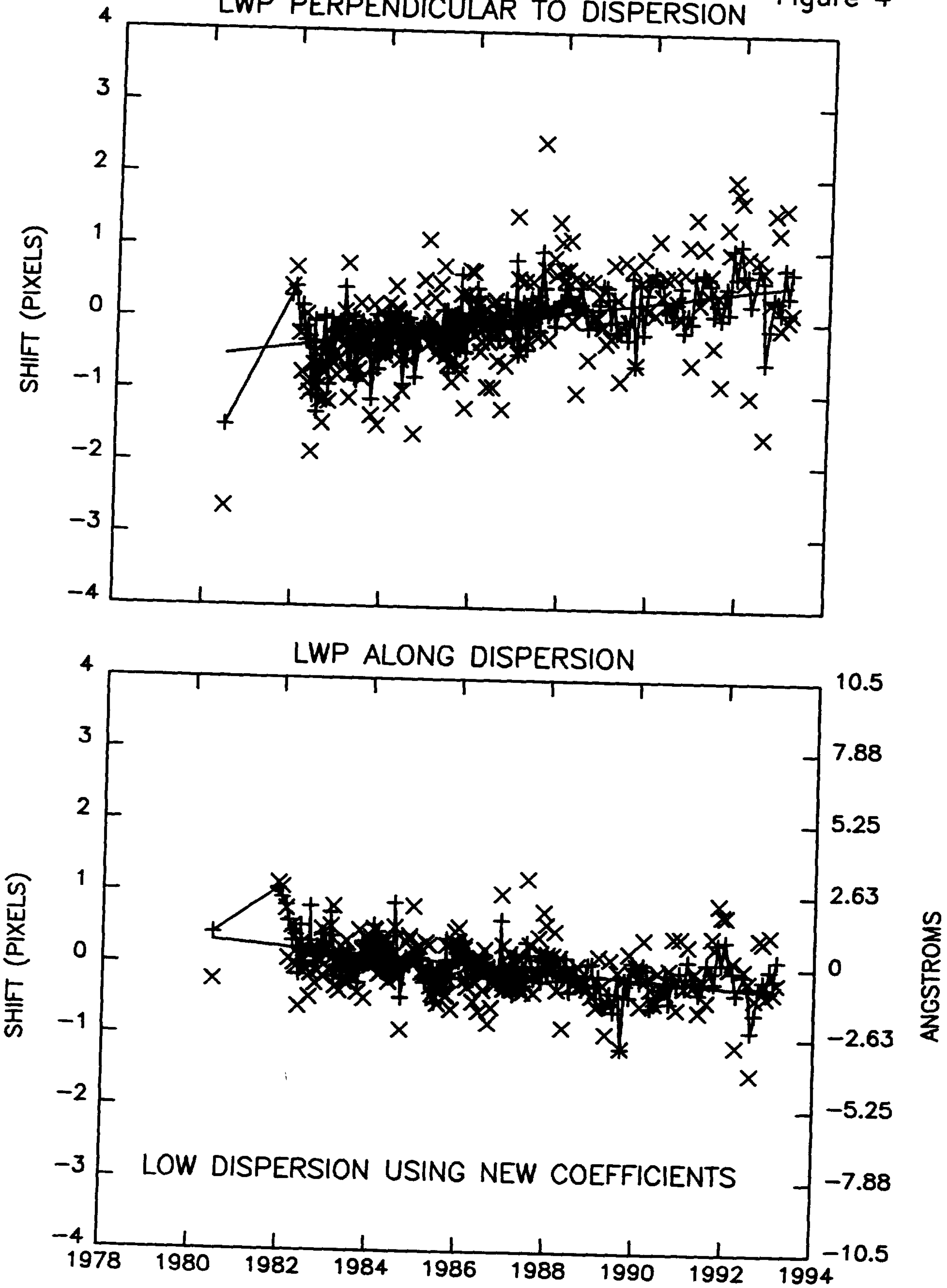
1986
1988
1990
1992
1994

Figure 4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SHIFT (PIXELS)
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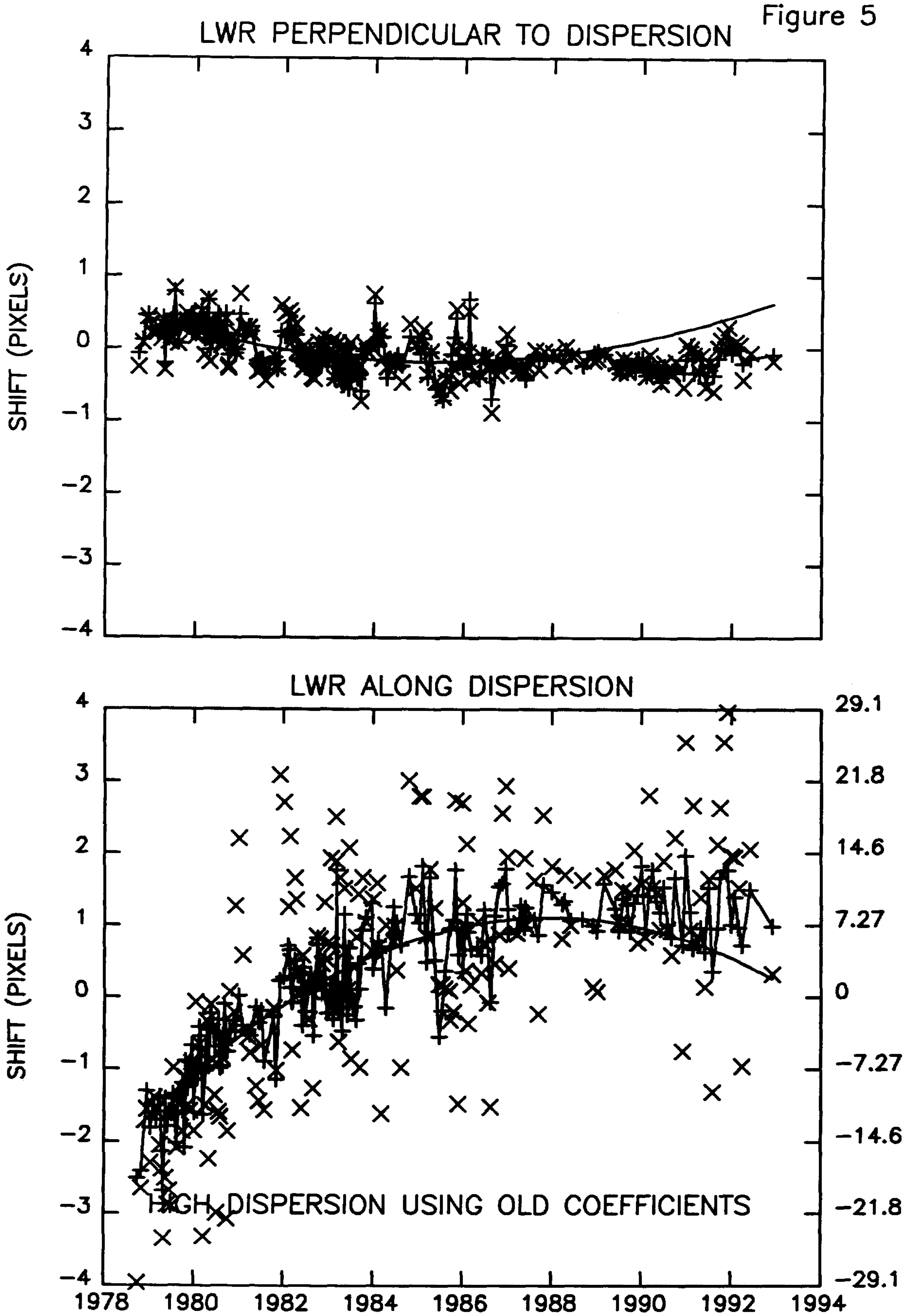
3
2
1
0
−1
−2
−3
−4
LWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 5


LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING OLD COEFFICIENTS
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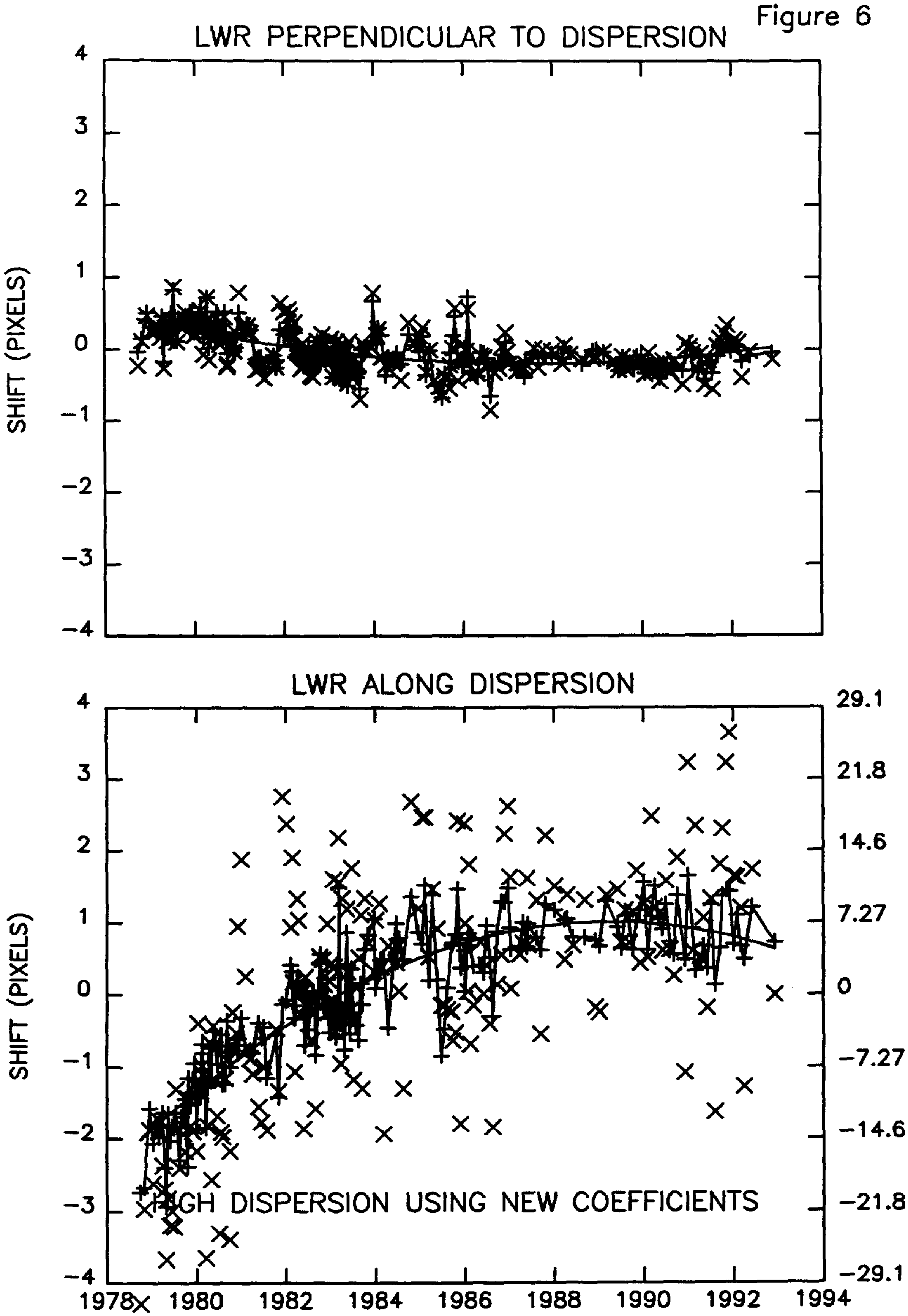
1992
1994

Figure 6



LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
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3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
29.1
21.8
14.6
7.27
0
−7.27
−14.6
−21.8
−29.1
HIGH DISPERSION USING NEW COEFFICIENTS
1978
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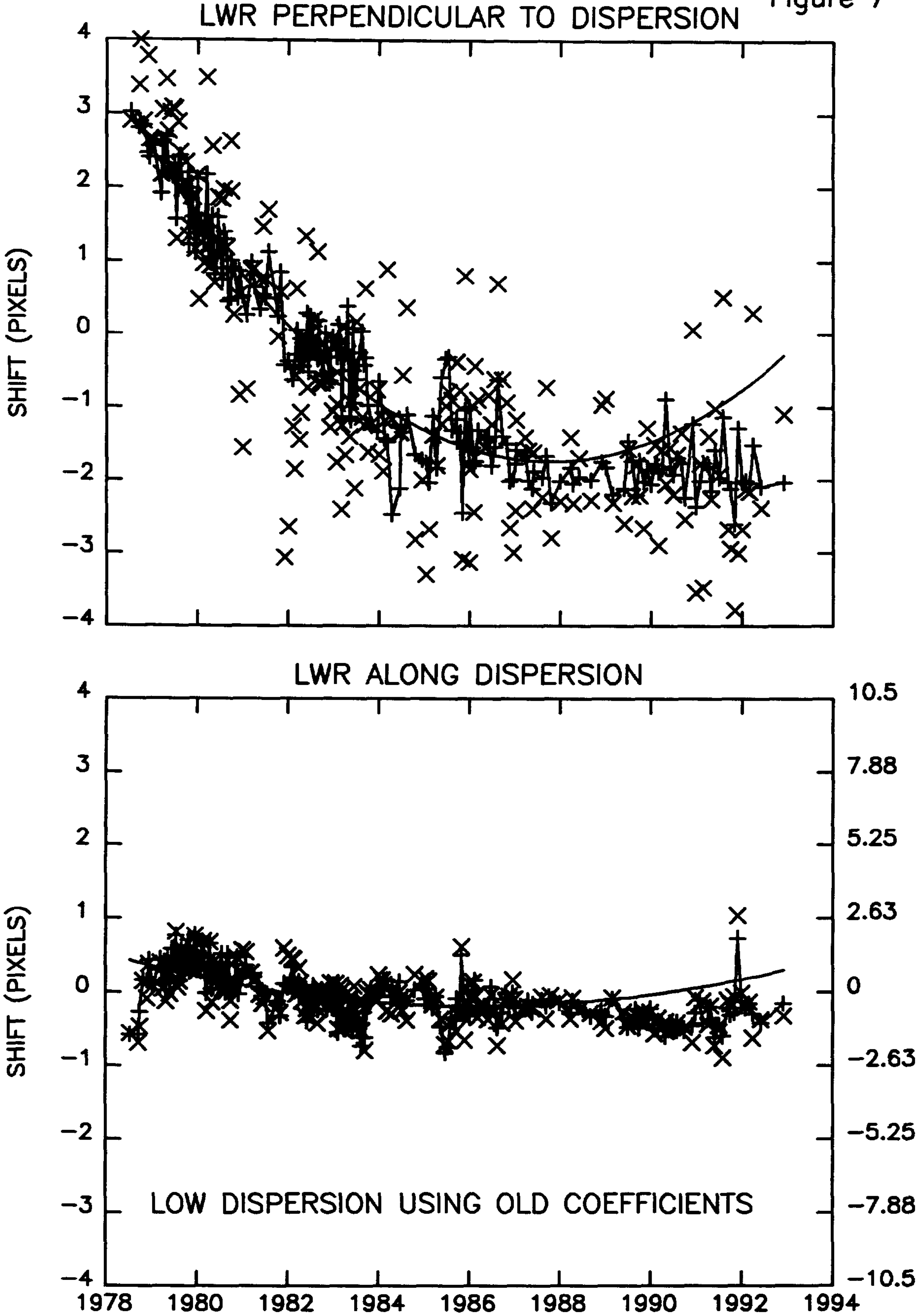
1992
1994

Figure 7



LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING OLD COEFFICIENTS
1978
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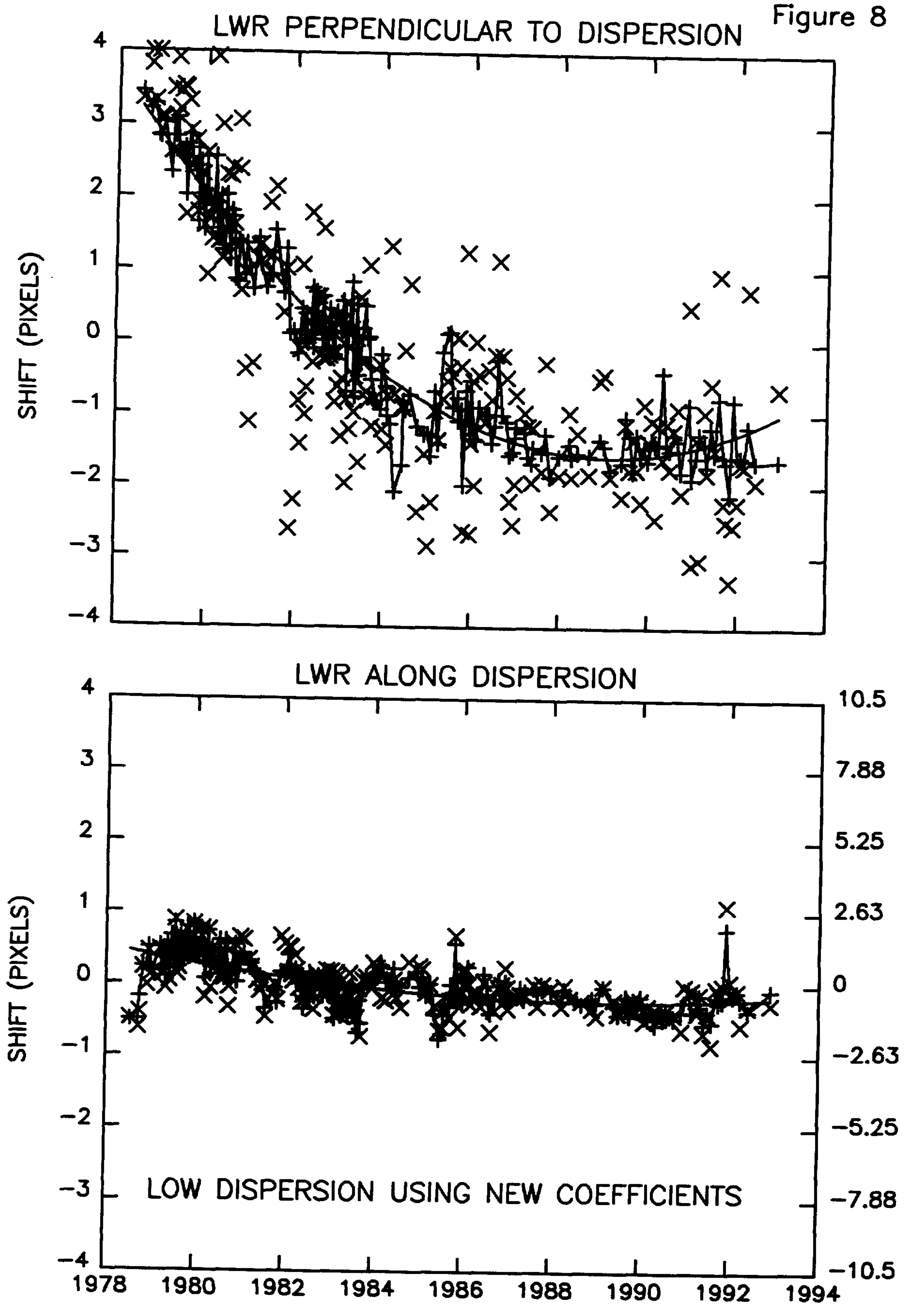
1994

Figure 8


LWR PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
LWR ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
10.5
7.88
5.25
2.63
0
−2.63
−5.25
−7.88
−10.5
LOW DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
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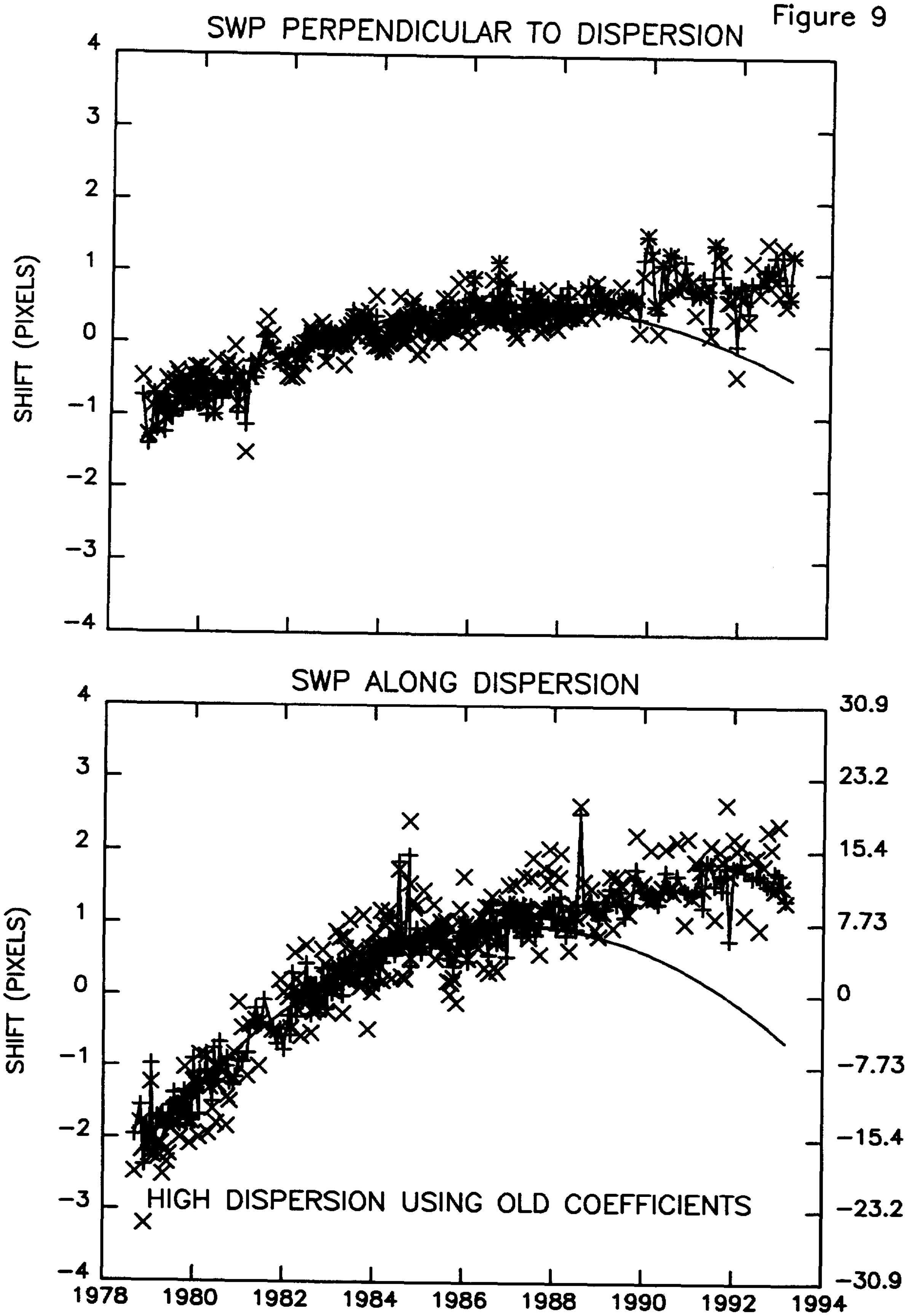
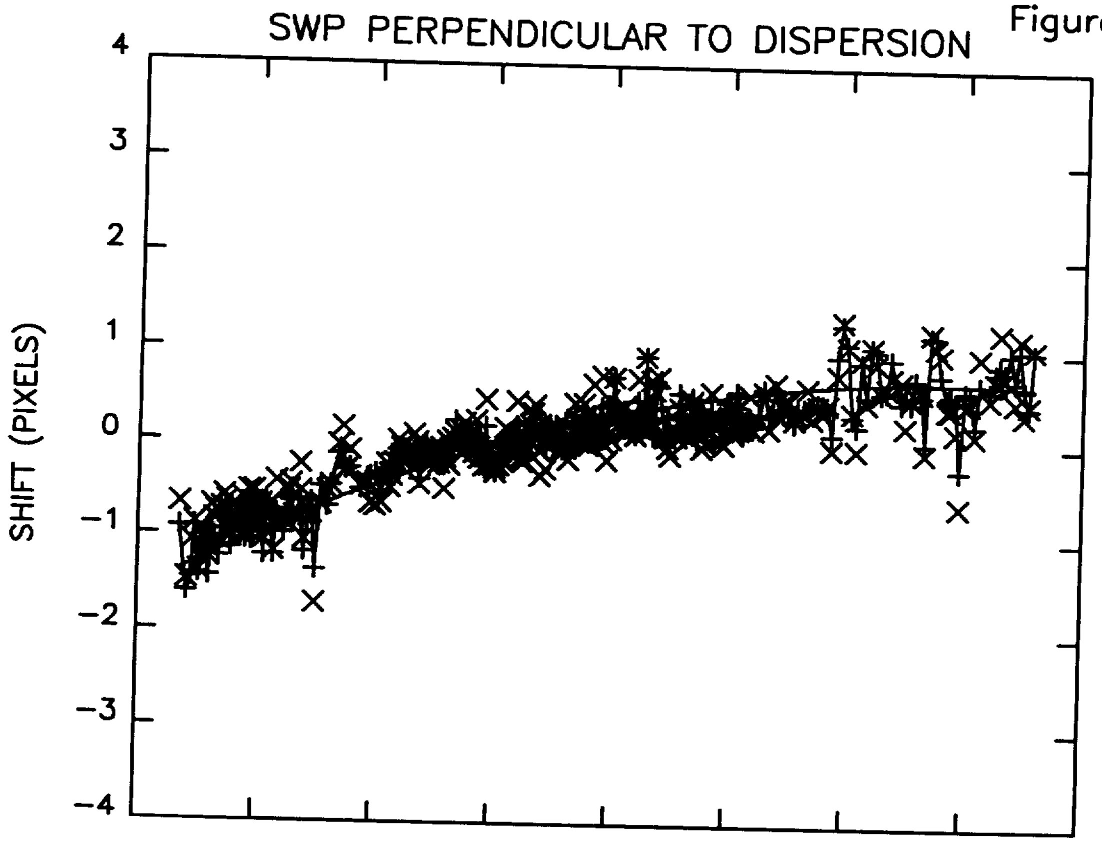
1986
1988
1990
1992
1994

Figure 9



SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
SWP ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
30.9
23.2
15.4
7.73
0
−7.73
−15.4
−23.2
−30.9
HIGH DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 10


SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4

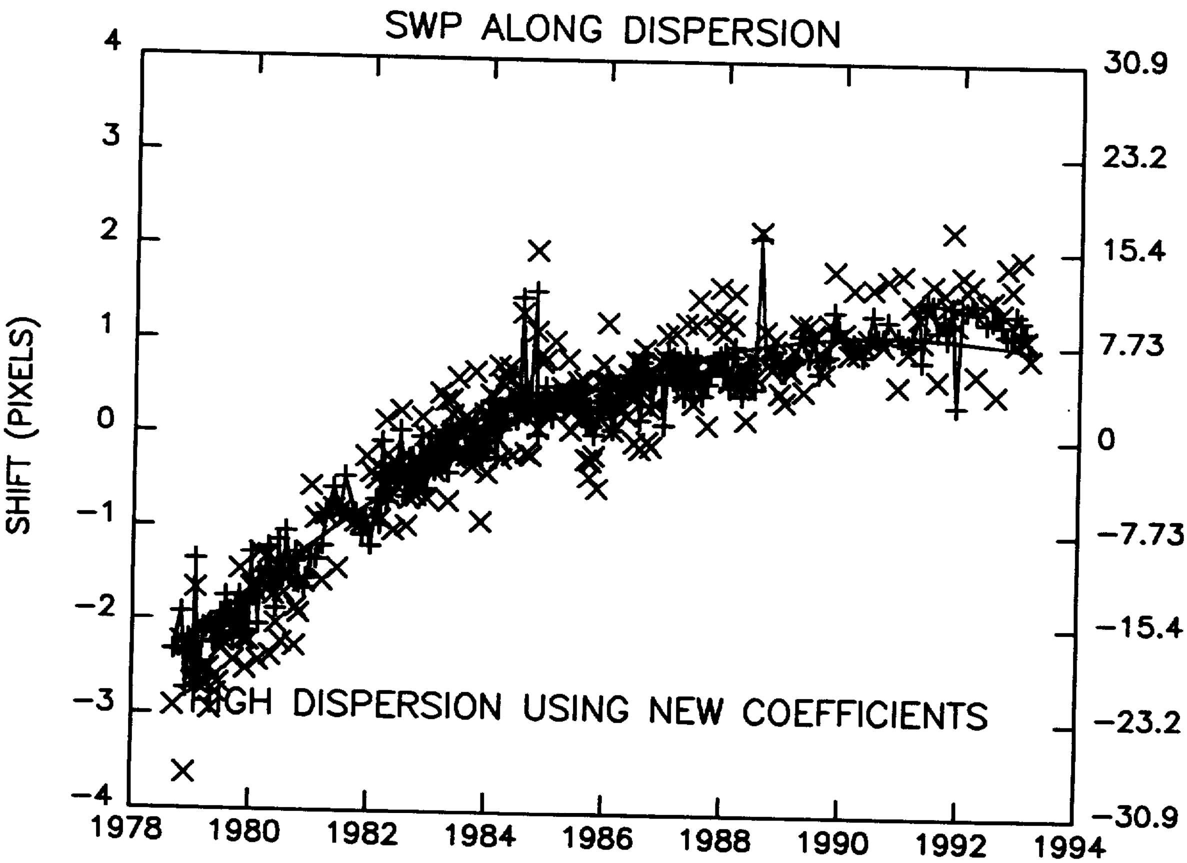
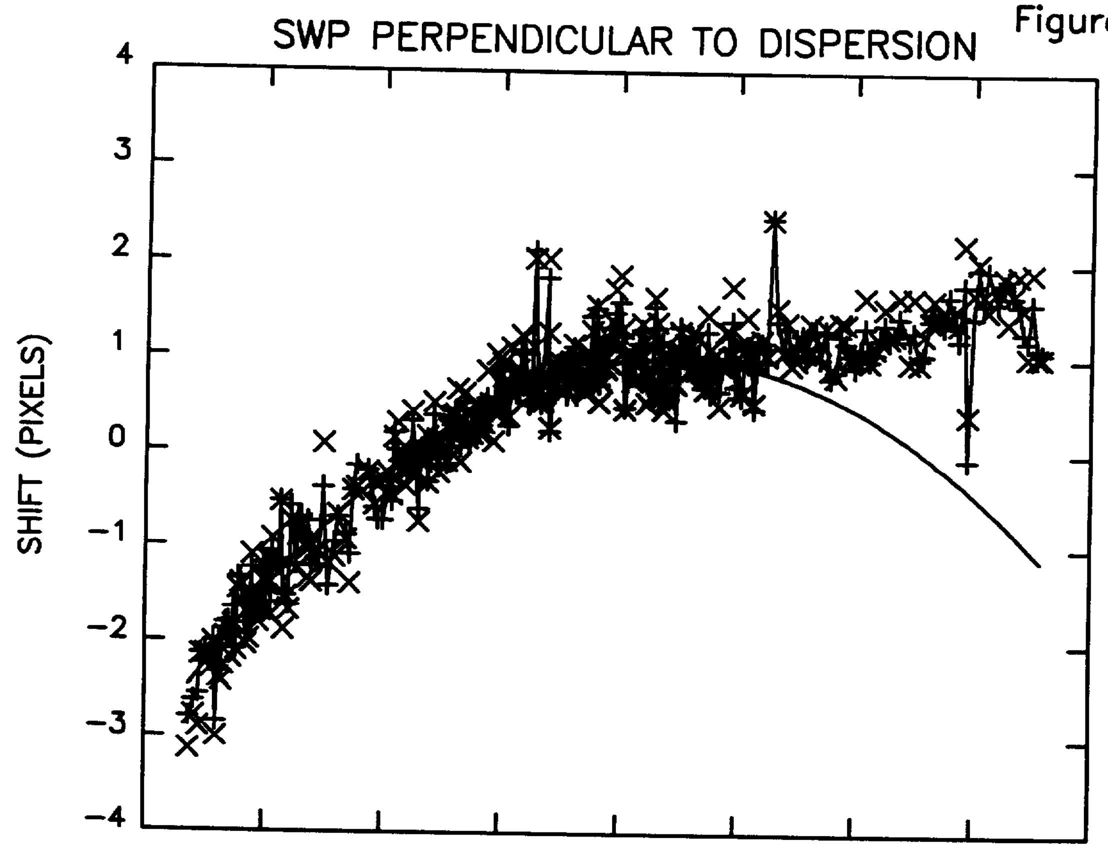
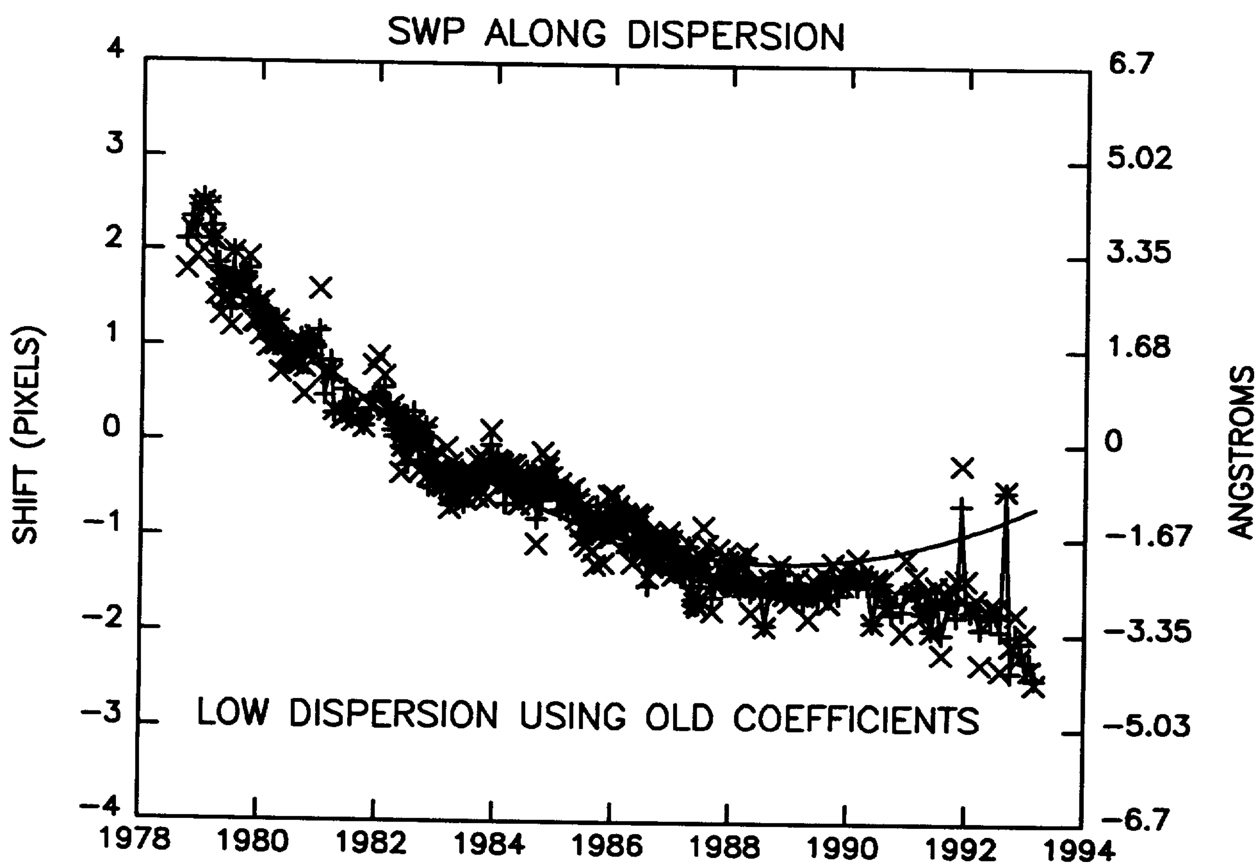

SWP ALONG DISPERSION
SHIFT (PIXELS)
VELOCITY (KM/S)
HIGH DISPERSION USING NEW COEFFICIENTS
4
3
2
1
0
−1
−2
−3
−4
30.9
23.2
15.4
7.73
0
−7.73
−15.4
−23.2
−30.9
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 11



SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4



SWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
4
3
2
1
0
−1
−2
−3
−4
6.7
5.02
3.35
1.68
0
−1.67
−3.35
−5.03
−6.7
LOW DISPERSION USING OLD COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 12

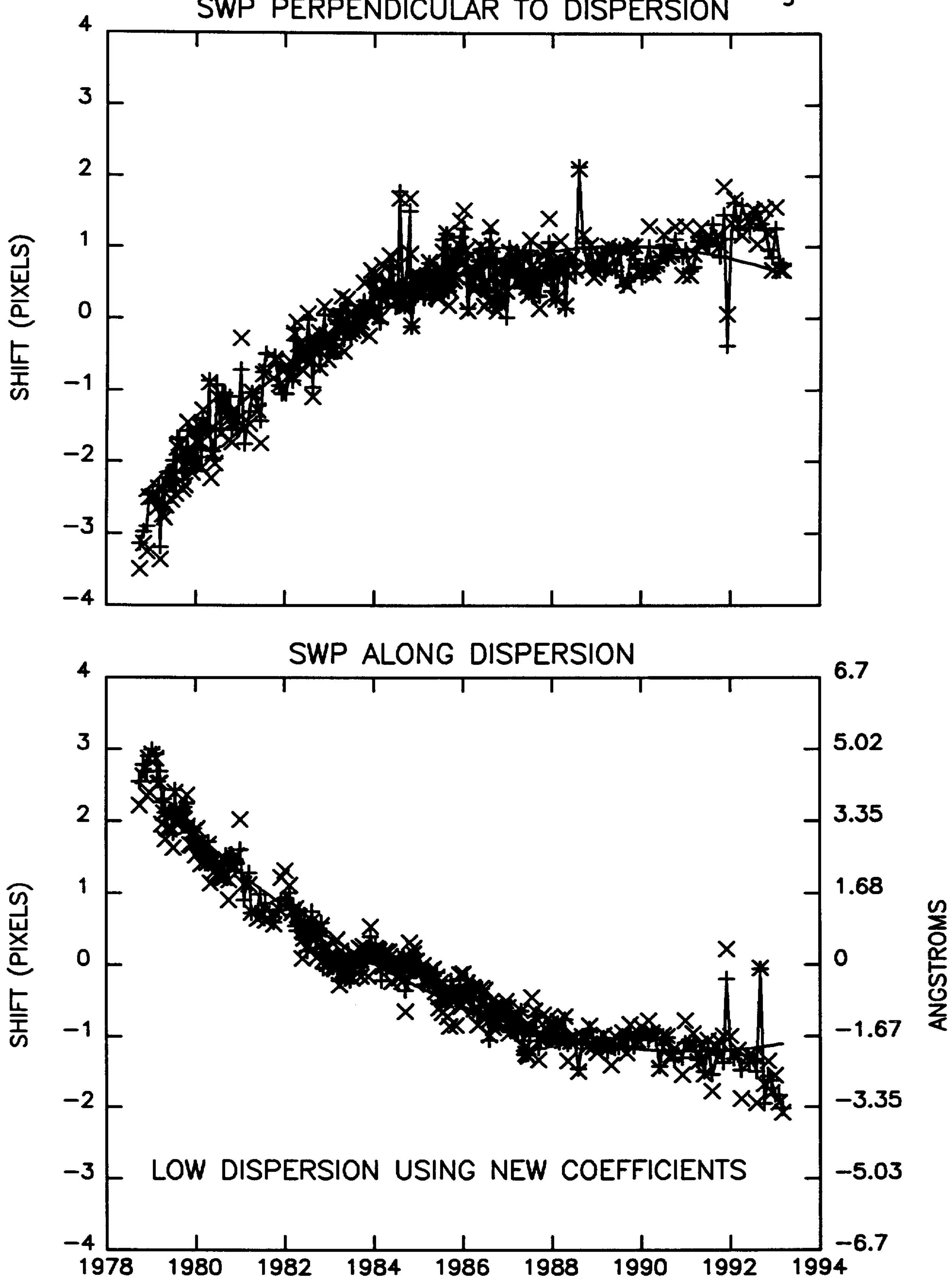

SWP PERPENDICULAR TO DISPERSION
SHIFT (PIXELS)
4
3
2
1
0
−1
−2
−3
−4
SWP ALONG DISPERSION
SHIFT (PIXELS)
ANGSTROMS
6.7
5.02
3.35
1.68
0
−1.67
−3.35
−5.03
−6.7
LOW DISPERSION USING NEW COEFFICIENTS
1978
1980
1982
1984
1986
1988
1990
1992
1994

Figure 13

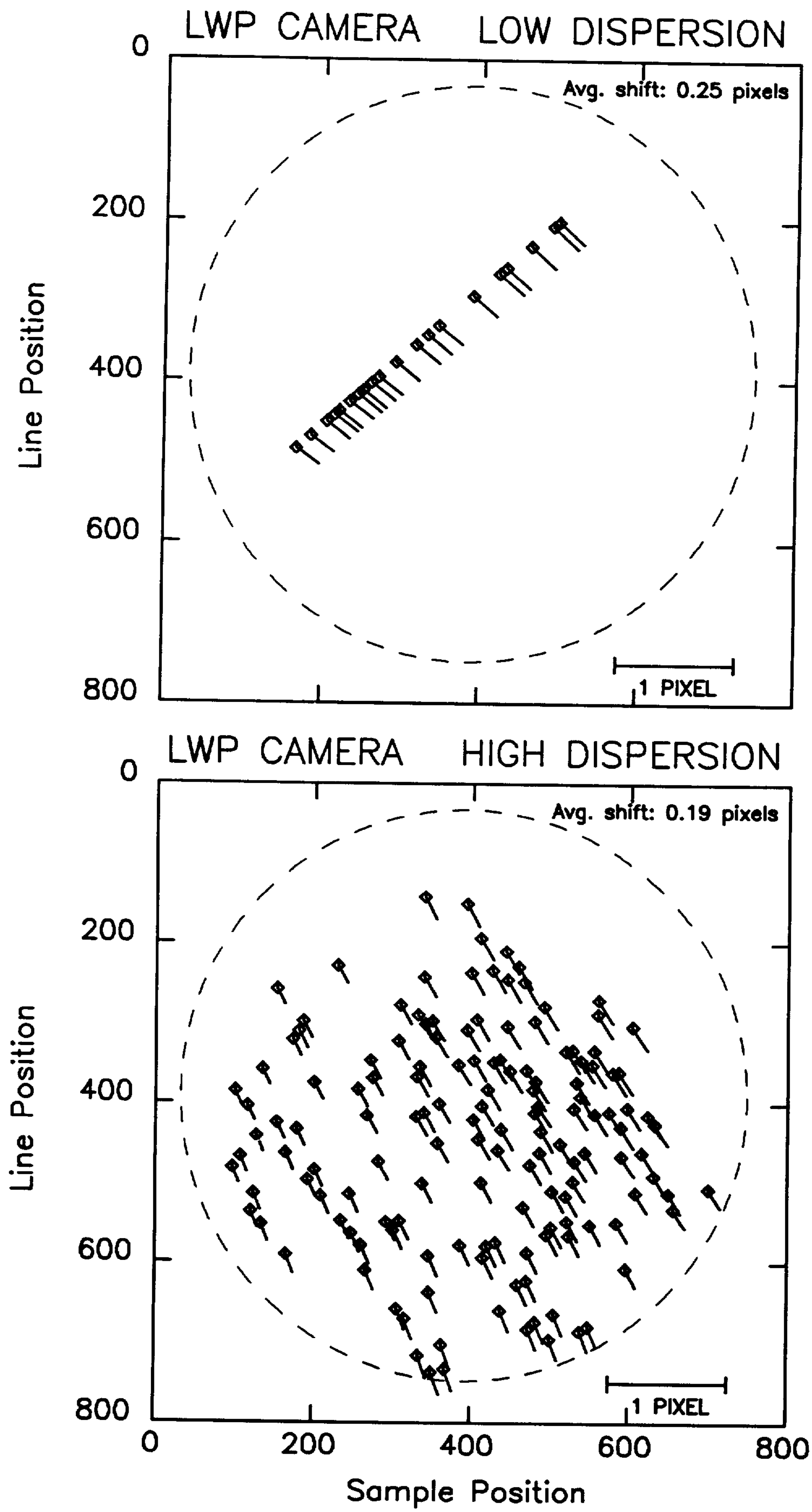
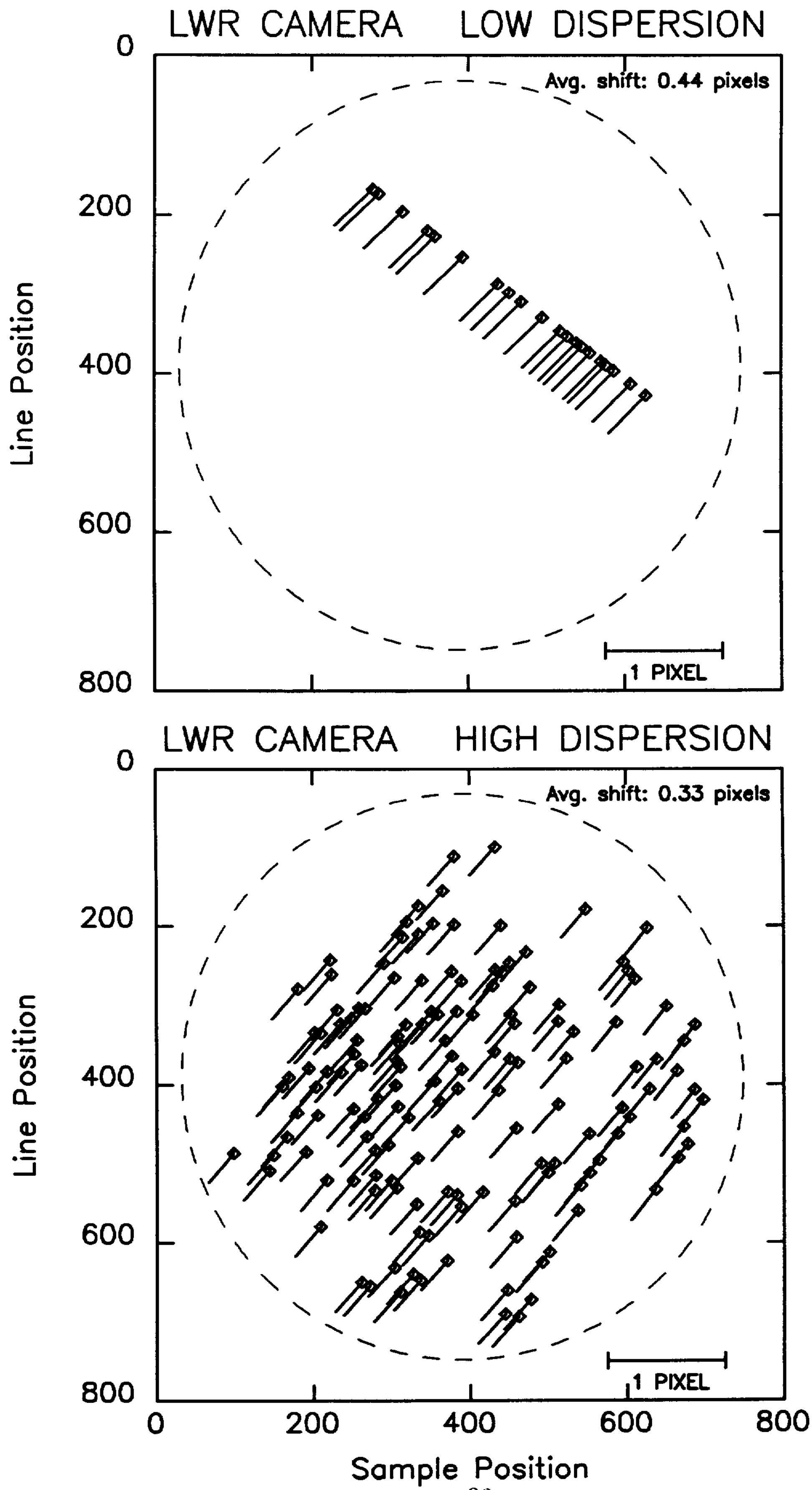
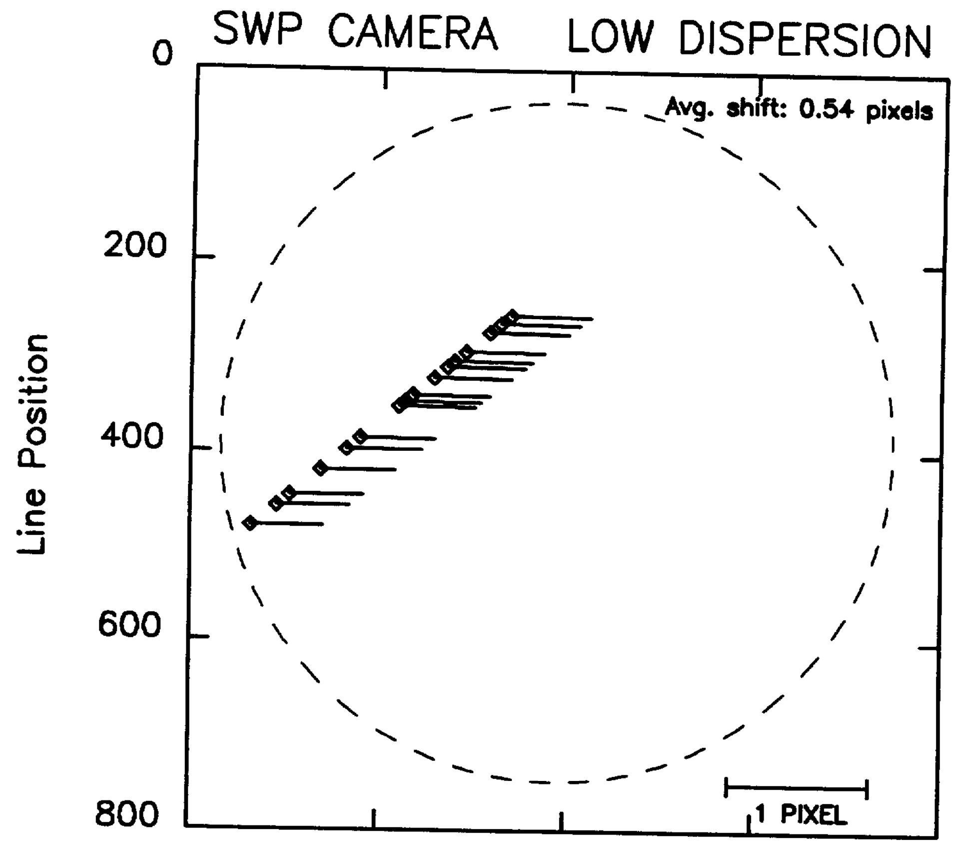

LWP CAMERA LOW DISPERSION
Avg. shift: 0.25 pixels
1 PIXEL
Line Position
0
200
400
600
800
LWP CAMERA HIGH DISPERSION
Avg. shift: 0.19 pixels
1 PIXEL
Line Position
0
200
400
600
800
0
200
400
600
800
Sample Position

Figure 14

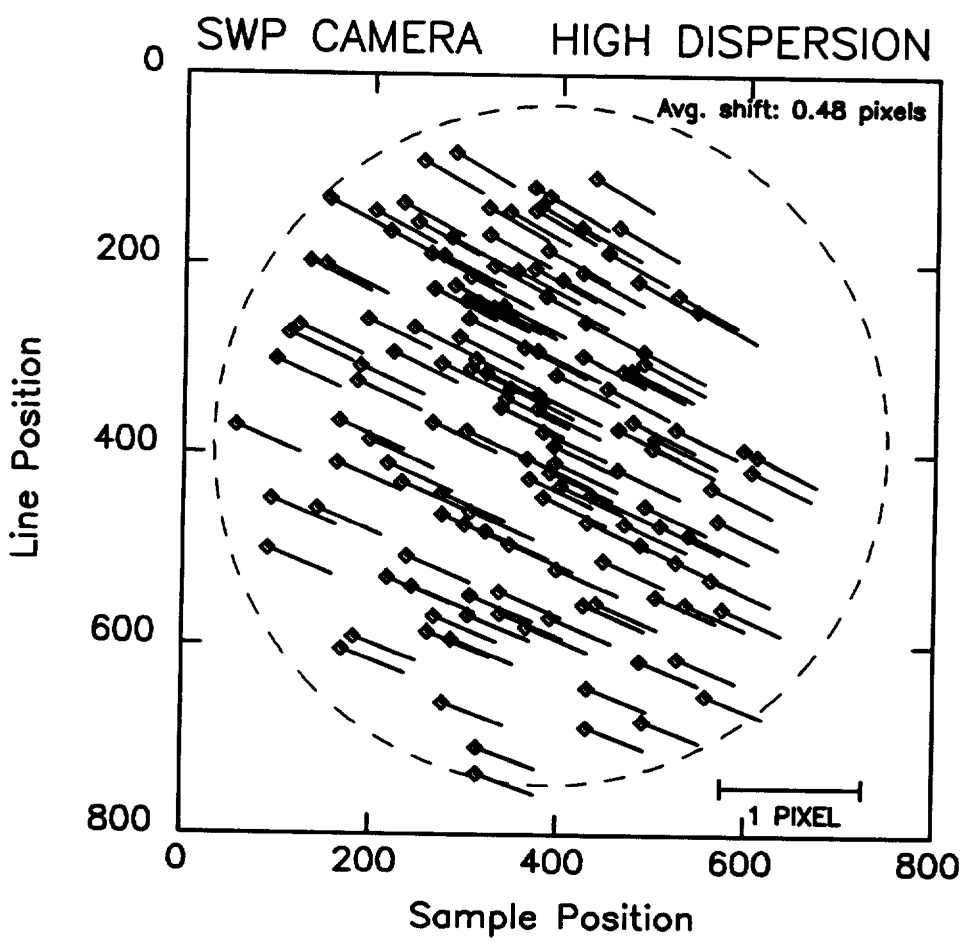


LWR CAMERA LOW DISPERSION
Avg. shift: 0.44 pixels
1 PIXEL
Line Position
0
200
400
600
800
LWR CAMERA HIGH DISPERSION
Avg. shift: 0.33 pixels
1 PIXEL
Line Position
0
200
400
600
800
0
200
400
600
800
Sample Position

Figure 15



SWP CAMERA LOW DISPERSION
Avg. shift: 0.54 pixels
1 PIXEL
Line Position
0
200
400
600
800



SWP CAMERA HIGH DISPERSION
Avg. shift: 0.48 pixels
1 PIXEL
Line Position
Sample Position
0
200
400
600
800