Repeatability of the FOS G130H Grating External Wavelength Zeropoint

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Abstract

Measurements of the position of the geo-coronal Lyα are used to determine the repeatability of the G130H grating and the external wavelength zeropoint for the first time since launch. From 10 observations with the 0.3″ aperture we find the offset from the rest wavelength (vacuum) of the geo-coronal Lyα to be 1.43 ± 0.66 pixels (4 pixels = 1 diode), which translates to 0.356Å ± 0.165Å or 88 ± 41 kms^{-1}. The 1σ repeatability of the wavelength calibration is 0.159Å or 0.64 pixels or 39 kms^{-1}. Pre-flight measurements for the FOS blue detector showed that the filter-grating wheel repeatability was ~0.8 pixels which is similar to that observed in the present analysis (~0.6 pixels).

1. Introduction

Pre-flight measurements of the FOS filter-grating wheel (FGW) repeatability showed that the FGW repeatability was of the order of 10 microns (10 y-bases units in Y and 0.2 diodes in X) in both the X and Y directions of the FOS blue detector (CAL/FOS-012, CAL/FOS-017, CAL/FOS-049). This non-repeatability of the FGW leads to some photometric and wavelength calibration errors. The FGW repeatability has not been determined accurately since launch (a test is scheduled during cycle 4). An independent technique to determine the FGW non-repeatability at least in the dispersion direction (FOS X-direction) is to use the geo-coronal Lyα. In this instrument science report we have analyzed all G130H grating observations using the 0.3″ aperture obtained so far in cycle 4 to estimate the FGW repeatability in the dispersion direction and the errors in the wavelength calibration.

2. Data Analysis

All cycle 4 observations (35 observations of 17 independent objects) obtained so far which used the G130H grating and the 0.3″ aperture were used in the following analysis. The location of the geo-coronal Lyα feature in each spectrum is determined by fitting a Gaussian to the line between 1214Å and 1218Å. The results of the fits are shown in Table 1. The measurement error in the position of the geo-coronal Lyα is 0.02Å (determined by fitting the line many times at different continuum levels). For objects with multiple exposures, the individual spectra are co-added and once again the location of the geo-coronal Lyα determined as before. Table 2 shows the position of the geo-coronal Lyα for each individual object used in the analysis. To calculate the zero-point wavelength offset, the vacuum wavelength for the geo-coronal Lyα (1215.6701Å) is used.

3. Results

3.1 Repeatability of the Wavelength Calibration from Consecutive Orbits

Since some of the objects in our sample have multi-orbit data, we can investigate the repeatability of the wavelength calibration from orbit to orbit. Any scatter in the position of the geo-coronal Lyα from orbit to orbit can be associated to measuring errors (of the order of 0.02Å), and external effects associated with the changes in the magnetic field environment of the FOS detector. The scatter is independent of the FGW, since there was no motion of the FGW. From Table 1 column 6 we see that the repeatability of the position of the geo-coronal Lyα has a 1σ uncertainty of 0.243Å and a range of –0.2 to +0.6Å. Target reacquisition uncertainties do not affect the observed scatter since the geo-coronal Lyα fills the aperture. Most of the scatter that we see in the wavelength calibration from consecutive orbits is likely due to changes in the magnetic environment of the FOS, although some of the scatter could be due to changes in the geo-coronal Lyα velocity field.

3.2 Repeatability of the Wavelength Calibration

The uncertainty of the wavelength calibration can be determined by investigating the repeatability of the position of the geo-coronal Lyα. This uncertainty of the wavelength calibration is mostly due to internal effects associated with grating wheel movement and residual magnetic field errors. It is very difficult to separate the effects of the grating wheel from the effects of the residual magnetic field to understand the exact source of the wavelength calibration uncertainties. The repeatability of the position of the geo-coronal Lyα is determined by comparing the location of the geo-coronal Lyα in each observation relative to a given observation. From Table 2 column 5 we see that the repeatability of the position of the geo-coronal Lyα has a 1σ uncertainty of 0.159Å and a range of ±0.3Å. This uncertainty translates to a 1σ uncertainty 0.64 pixels (4 pixels = 1 diode) and a range of ±1.2 pixels for the G130H grating. This uncertainty is smaller than the uncertainty in consecutive orbits because of the averaging of the spectra. The FGW repeatability seen in this analysis is of the same order as observed during the preflight measurements. Since all the gratings are on the same grating wheel, they are likely to have similar repeatability in pixel units. However, to check this a proper FGW repeatability test has to be done, since the individual mechanical indents associated with the gratings may have different wear histories. Thus, the relative uncertainty of the FOS wavelength calibration from the present analysis of the G130H grating observations is 0.159Å (0.64 pixels) with a range of ±0.3Å (±1.2 pixels).

3.3 The Zeropoint Offset of the G130H Grating

The zeropoint offset of the G130H grating can be determined by comparing the observed average position of the geo-coronal Lyα with the vacuum rest wavelength of the line. This offset is mostly due to the errors in the wavelength dispersion solution and the internal and external offset corrections applied in the pipeline. There is no contribution to the zeropoint offset from the external effects associated with target acquisition, because the geo-coronal Lyα fills the aperture. The measurements of the geo-coronal Lyα from column 3 of Table 2 show that the line center is offset from the vacuum rest wavelength position by -0.358Å ± 0.165Å. This offset translates to 1.43 ± 0.66 pixels, or 88 ± 41 kms^{-1}. This uncertainty is a measure of the absolute accuracy of the FOS wavelength calibration for the G130H grating.

References

Hartig, G. 1984, FOS Filter-Grating Wheel Repeatability, CAL/FOS-12,
Hartig, G. 1985, Improvements in the filter-grating Wheel Repeatability, CAL/FOS-17
Hartig, G. 1988, FOS Filter-Grating Wheel Repeatability, CAL/FOS-49

Table 1: Position of the geo-coronal Lyα

Prop ID	Object	Dataset	Line Center (Å)	Line Width (Å)	Line Shift (Å)	Notes
5339	PK316+8D1	y25p0105t	1216.023	0.935	0.000	
5339	PK316+8D1	y25p0106t	1216.036	0.899	0.013	
5346	SK-69D43	y25t0105t	1216.100	1.098	N/A	
5346	SK-67D14	y25t0305t	1216.755	0.145	N/A	no line observed
5346	SK-69D228	y25t0405t	1216.047	0.911	N/A	
5460	BR93	y2a10104t	1216.410	1.074	0.262	
5460	BR93	y2a10105t	1216.148	1.067	0.000	
5460	BR93	y2a10106t	1216.044	1.293	-0.104	
5460	HD32125	y2a10204t	1215.691	0.375	-0.184	faint line observed in y2a10204t
5460	HD32125	y2a10205t	1215.875	1.088	0.000	
5379	3C279	y2ey0603t	1215.820	0.736	0.000	
5379	3C279	y2ey0604t	1215.915	1.065	0.095	
5379	3C279	y2ey0605t	1215.787	1.121	-0.033	
5664	OJ287	y2ie0705t	1216.428	0.314	0.369	
5664	OJ287	y2ie0706t	1216.059	1.121	0.000	
5664	OJ287	y2ie0707t	1215.961	1.279	-0.098	
5664	OJ287	y2ie0708t	1215.981	0.816	-0.078	
5664	OJ287	y2ie0709t	1216.068	1.010	0.009	
5664	PKS1302-102	y2ie0f04t	1216.089	0.900	-0.095	
5664	PKS1302-102	y2ie0f05t	1216.184	1.037	0.000	
5664	PKS1302-102	y2ie0f06t	1216.122	0.974	-0.062	
5664	PKS1302-102	y2ie0f07t	1216.173	0.694	-0.011	
5723	HD32402	y2je0105t	1215.920	1.123	0.000	definite grating shift observed
5723	HD32402	y2je0106t	1216.340	0.515	0.420	

Table 1: Position of the geo-coronal Lyα

Prop ID	Object	Dataset	Line Center (Å)	Line Width (Å)	Line Shift (Å)	Notes
5723	HD37026	y2je0205t	1216.001	0.845	0.000	definite grating shift observed
5723	HD37026	y2je0206t	1216.274	1.054	0.273	
5723	HD37680	y2je0305t	1216.251	0.524	0.000	faint line observed in both observations
5723	HD37680	y2je0306t	1216.056	0.627	-0.195	
5723	HD32257	y2je0404t	1215.245	0.372	0.000	very faint line observed in each observation, definite grating shift observed
5723	HD32257	y2je0405t	1215.874	0.402	0.629	
5723	HD32402	y2je0505t	1216.185	1.218	N/A	
Standard Deviation					0.243	

Table 2: Position of the geo-coronal Lyα

Prop ID	Object	Line Center (Å)	Line Width (Å)	Internal Repeatability (Å)
5339	PK316+8D1	1216.030	0.910	0.000
5346	SK-69D43	1216.100	1.098	0.070
5346	SK-69D228	1216.047	0.911	0.017
5460	BR93	1216.184	1.102	0.154
5460	HD32125	1215.835	1.188	-0.195
5379	3C279	1215.824	0.975	-0.206
5664	OJ287	1216.060	0.985	0.030
5664	PKS1302-102	1216.121	0.905	0.091
5723	HD32402	1216.271	0.834	0.240
5723	HD37026	1216.118	0.837	0.088
5723	HD37680	1215.853	1.175	-0.177
5723	HD32257	1215.732	1.077	0.298
5723	HD32402	1216.185	1.218	0.155
Average		1216.028		
Standard Deviation		0.165		0.159