JWST TECHNICAL REPORT

Title: NIRISS Commissioning Results: NIS-016 GR150C and GR150R Grism Wavelength Calibration (NGAS CAR 700, APT 1090)	Doc #: JWST-STScI-008296, SM-12 Date: 10 October 2022 Rev: -
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1 Abstract

We present the analysis and results of the commissioning activity NIS-016 GR150C and GR150R Grism Wavelength Calibration (CAR 700, APT 1090). The target is the planetary nebula SMP LMC 58, which partially saturates in full frame, hence the calibration is verified using the WFSS64R subarray. During this activity, the wavelength calibration is performed only in the center of the field of view (FOV). The wavelength dispersions of order 1 (47.015 Å/pix for GR150C and 46.939 Å/pix for GR150R) and order 2 (23.864 Å/pix for GR150C and 23.859 Å/pix for GR150R) match the calibration derived in ground testing. We find smaller uncertainties in GR150R than in GR150C, but could not identify a clear culprit for the difference. We conclude that both grisms are healthy and we will investigate the differences between the two grisms using Cycle 1 calibration observations.

2 Introduction

The wavelength dispersion solution was measured at the center of the NIRISS FOV using the 1st and 2nd orders of the spectra. The target is a small emission-line planetary nebula (PN), SMP LMC 58 (K-band Vega magnitude of 14.6). A compact source (size ~0.08") offers the advantage of measuring more accurately the zero point of the wavelength dispersion and of better characterizing the true resolution and line spread function of the grism as a function of wavelength. Emission lines in all blocking filters are necessary to properly calibrate the wavelength solution over the full wavelength range, from 0.8 to 2.2 µm. The field is crowded (Figure 1), hence the position angle (PA) had been checked in advance to make sure the traces of the PN do not overlap with the traces of other sources. The target was observed in full frame. Additional exposures were collected in the calibration subarray WFSS64R to avoid any saturation in the emission lines. The observations were executed with fine guiding on Jun 1, 2022 at 17:25:13.371 UTC and had a total duration of 5.4 hours (1.51 hours on target). The results of this Commissioning Activity Request (CAR) were used in conjunction with the results of NIS-015 (WFSS Flux Calibration program, in prep.) to update the *specwcs* reference files (i.e., the world coordinate system, WCS, reference and distortion correction reference file) for all filters and grisms. We note that this activity was described in its associated CAR and presented along with the other activities in Martel (2021).

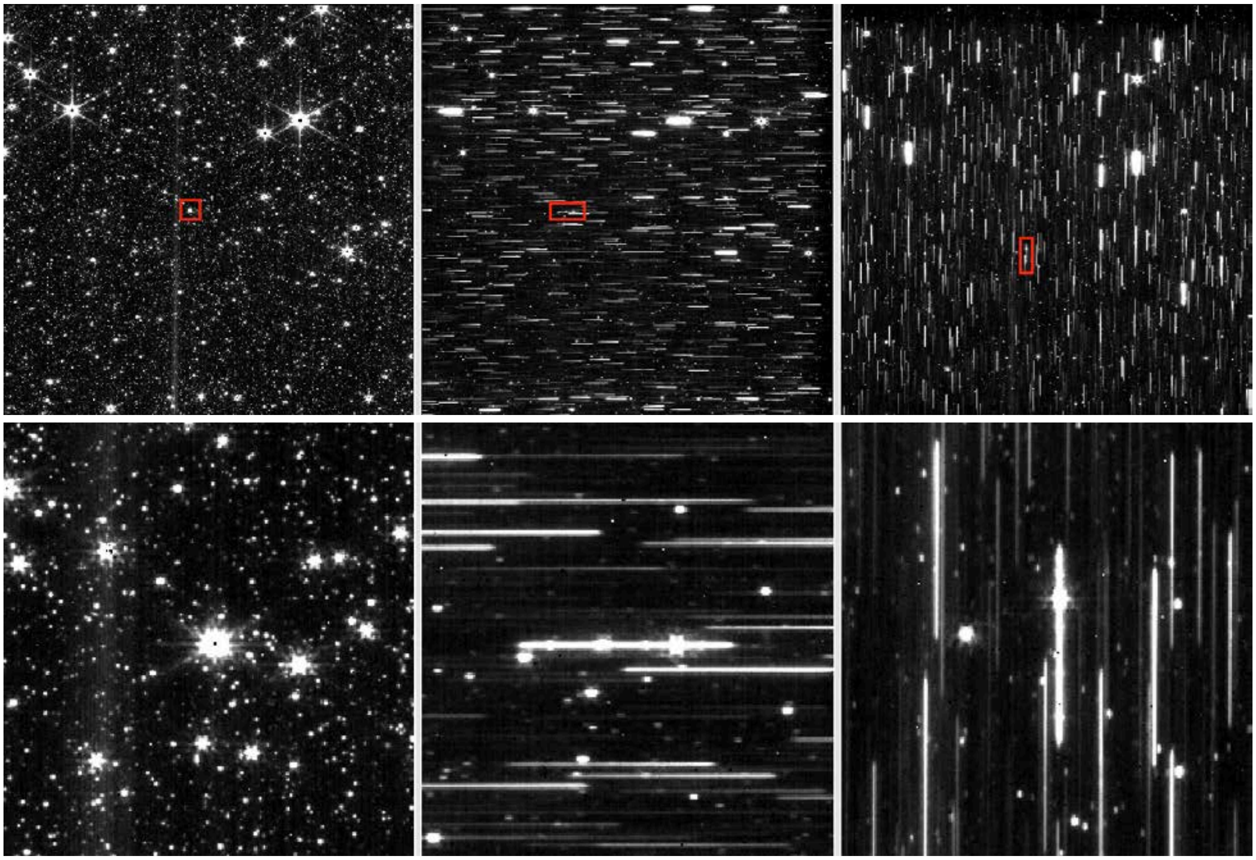


Figure 1. Top, from left to right: Imaging and WFSS observations (GR150C in the center and GR150R to the right) of the PN with the F200W filter for the full 2.2 x 2.2 arcmin field of view of NIRISS (2048 x 2048 pixels); The PN and its spectra are highlighted with red boxes. Bottom: A zoom to the PN and its spectra in square regions of ~200 pixels per side.

3 Exposures

In Tables 1 and 2, we list the exposures that were collected in the two observations of program 1090. Observation 1 was in full frame and observation 2 used the subarray WFSS64R. All the exposures were read out with the NISRAPID pattern. The dither pattern used 4 dithers with medium size pattern for observation 1 and small size pattern for observation 2.

Table 1. Exposures and filenames for Observation 1.

Filter Pupil	NINTS	NGROUPS	Dithers	Level1b
CLEAR F090W	1	5	1	jw01090001001_02101_00001_nis_uncal.fits
GR150C F090W	1	5	4	jw01090001001_03101_00001_nis_uncal.fits
CLEAR F090W	1	5	1	jw01090001001_04101_00001_nis_uncal.fits
CLEAR F090W	1	5	1	jw01090001001_06101_00001_nis_uncal.fits
GR150R F090W	1	5	4	jw01090001001_07101_00001_nis_uncal.fits

Filter Pupil	NINTS	NGROUPS	Dithers	Level1b
CLEAR F090W	1	5	1	jw01090001001_08101_00001_nis_uncal.fits
CLEAR F115W	1	5	1	jw01090001001_10101_00001_nis_uncal.fits
GR150R F115W	1	5	4	jw01090001001_11101_00001_nis_uncal.fits
CLEAR F115W	1	5	1	jw01090001001_12101_00001_nis_uncal.fits
CLEAR F115W	1	5	1	jw01090001001_14101_00001_nis_uncal.fits
GR150C F115W	1	5	4	jw01090001001_15101_00001_nis_uncal.fits
CLEAR F115W	1	5	1	jw01090001001_16101_00001_nis_uncal.fits
CLEAR F158M	1	5	1	jw01090001001_18101_00001_nis_uncal.fits
GR150C F158M	1	10	4	jw01090001001_19101_00001_nis_uncal.fits
CLEAR F158M	1	5	1	jw01090001001_20101_00001_nis_uncal.fits
CLEAR F158M	1	5	1	jw01090001001_22101_00001_nis_uncal.fits
GR150R F158M	1	10	4	jw01090001001_23101_00001_nis_uncal.fits
CLEAR F158M	1	5	1	jw01090001001_24101_00001_nis_uncal.fits
CLEAR F150W	1	5	1	jw01090001001_26101_00001_nis_uncal.fits
GR150R F150W	1	10	4	jw01090001001_27101_00001_nis_uncal.fits
CLEAR F150W	1	5	1	jw01090001001_28101_00001_nis_uncal.fits
CLEAR F150W	1	5	1	jw01090001001_30101_00001_nis_uncal.fits
GR150C F150W	1	10	4	jw01090001001_31101_00001_nis_uncal.fits
CLEAR F150W	1	5	1	jw01090001001_32101_00001_nis_uncal.fits
CLEAR F200W	1	5	1	jw01090001001_34101_00001_nis_uncal.fits
GR150C F200W	1	5	4	jw01090001001_35101_00001_nis_uncal.fits
CLEAR F200W	1	5	1	jw01090001001_36101_00001_nis_uncal.fits
CLEAR F200W	1	5	1	jw01090001001_38101_00001_nis_uncal.fits
GR150R F200W	1	5	4	jw01090001001_39101_00001_nis_uncal.fits
CLEAR F200W	1	5	1	jw01090001001_40101_00001_nis_uncal.fits

Table 2. Exposures and filenames for Observation 2.

Filter Pupil	NINTS	NGROUPS	Dithers	Level1b
CLEAR F200W	3	5	4	jw01090002001_02101_00001_nis_uncal.fits
GR150R F200W	3	45	4	jw01090002001_02103_00001_nis_uncal.fits
GR150R F150W	2	150	4	jw01090002001_02105_00001_nis_uncal.fits
CLEAR F150W	3	5	4	jw01090002001_02107_00001_nis_uncal.fits
CLEAR F158M	3	10	4	jw01090002001_02109_00001_nis_uncal.fits
GR150R F158M	2	150	4	jw01090002001_0210b_00001_nis_uncal.fits
GR150R F115W	3	10	4	jw01090002001_0210d_00001_nis_uncal.fits

Filter Pupil	NINTS	NGROUPS	Dithers	Level1b
CLEAR F115W	3	5	4	jw01090002001_0210f_00001_nis_uncal.fits
CLEAR F090W	3	5	4	jw01090002001_0210h_00001_nis_uncal.fits
GR150R F090W	2	50	4	jw01090002001_0210j_00001_nis_uncal.fits

4 Analysis Steps

Data have been calibrated with the JWST Calibration Pipeline version 1.5.3a1.dev2+ga703491c. Stage 1 (Detector1) was executed in the default configuration. From Stage 2, we executed only the assign_wcs and flat_field steps.

First, we measured the centroid of the PN in the direct images using the method *photutils.centroids.centroid_sources*. This is the zeropoint for the position of the emission lines in the spectra. The PN saturates in the center (1 to 3 pixels), but we managed to derive accurate centroids by filling the saturated pixels using the maximum value within a box of 9x9 pixels and then calculating the center of mass within the same box. Direct images have not been taken at all dithered positions, so the centroid for the missing dithers was inferred using the dither offsets which are very precise from one exposure to the next.

1D spectra for order 1 in each filter and at each dithered position were extracted with a simple Boxcar extraction in a window of 8 pixels centered on the trace and column-by-column background subtraction using *numpy.nanmedian* to calculate the background in two stripes 20-pixels wide above and below the trace. The continuum of the PN was subtracted (with *specutils.fitting.fit_generic_continuum*) and emission lines were identified (with *specutils.fitting.find_lines_threshold*) at every dithered position. The centroid of each emission line was calculated with a Gaussian fit, using the method *specutils.fitting.fit_lines* and the *astropy.modeling.models.Gaussian1D* kernel. A model spectrum (curtesy of K. Volk) calculated with CLOUDY (Ferland 1996) and downgraded to the NIRISS resolution, along with the expected emission lines, is visualized in Figure 2. The expected wavelengths of the emission lines (accounting for the velocity of the source) were matched with the position of the emission lines with respect to the zeropoint in pixels from every dithered exposure at the same time. The wavelength solution was then derived using the method *astropy.modeling.fitting.LinearLSQFitter* and a linear or a second-order polynomial relation. The same analysis was run for both grisms from the full frame observations as well as the GR150R subarray observations. The same analysis was also performed for the order 2 spectra.

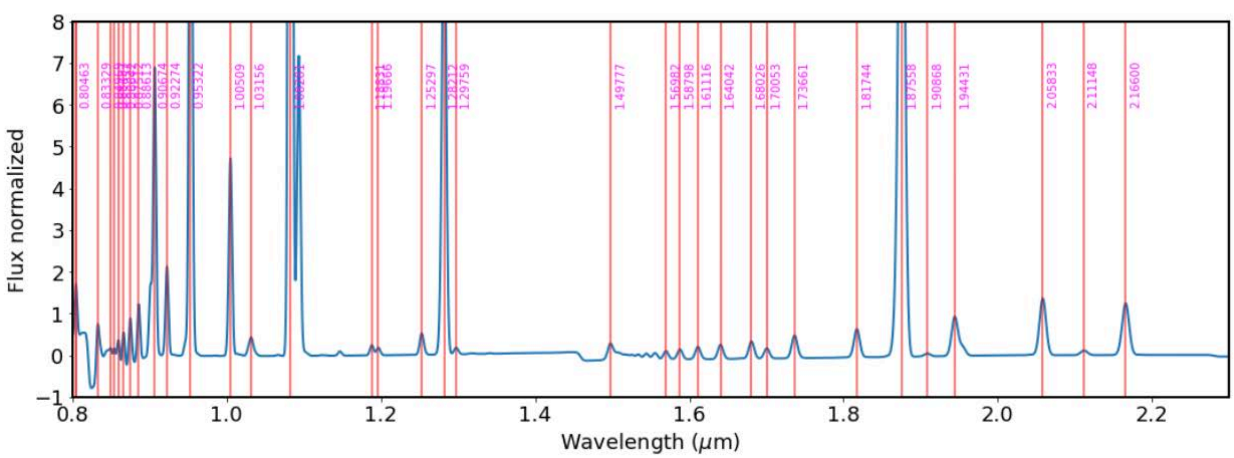


Figure 2. Model spectrum of the PN at the NIRISS resolution and marked emission line wavelengths.

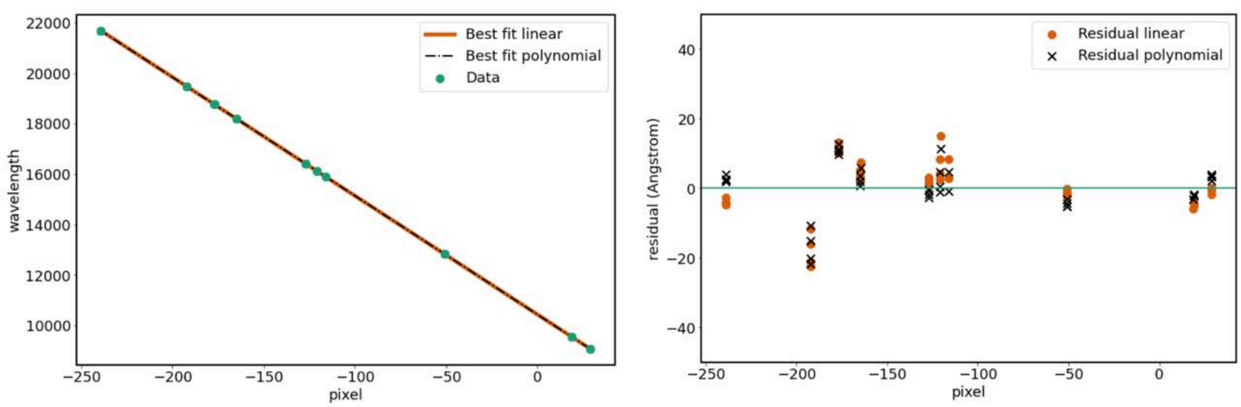
5 Results

The wavelength solutions for order 1 and order 2 are consistent with a linear relation for both grisms. The coefficient of the second-order term for the polynomial fit is negligible. The fits are also consistent with the results from ground testing (Ravindranath 2014), confirming that the grisms have remained healthy during launch. Results for GR150R in full frame and in the subarray WFSS64R (at the edge of the detector) are consistent with each other. We find the calibration in GR150C to have larger uncertainties than the calibration in GR150R. We could not identify a reason for this and we will investigate further during the Cycle 1 calibration program, along with the potential variations due to distortion at the corners of the field. We list the results in Table 3.

Table 3. Results for the wavelength solution with linear fit.

Field	Grism	Order	Intercept Å	Slope Å/pix	Slope uncertainty Å/pix	STD of the residuals Å
Full	GR150C	1	10441.247	-47.015	0.017	9.745
Full	GR150R	1	10269.215	-46.934	0.009	5.883
Subarray	GR150R	1	10295.05	-46.939	0.009	5.689
Full	GR150C	2	5287.334	-23.864	0.004	2.511
Full	GR150R	2	5189.390	-23.859	0.003	3.429

Figure 3 shows the fits (both linear and polynomial) and their residuals for the two grisms in full frame. Each emission line is sampled in at least 2 dithered positions. GR150C misses an emission line because of saturation and another one because of contamination by the order 0 spectrum of another object in the field. Figures 4 and 5 show the same plots for the subarray and for order 2, respectively.



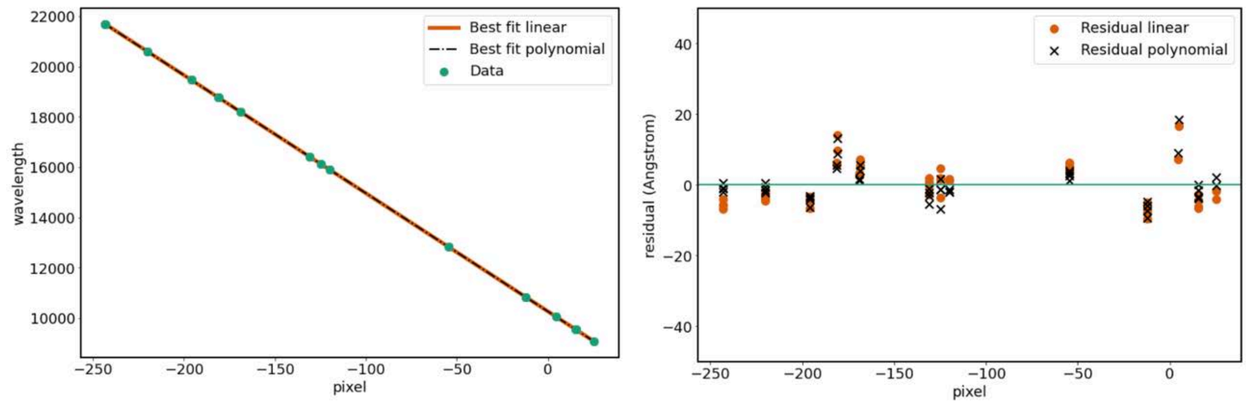


Figure 3. Top: wavelength solution fit (left) and residuals (right) for GR150C for order 1. Bottom: wavelength solution fit (left) and residuals (right) for GR150R for order 1.

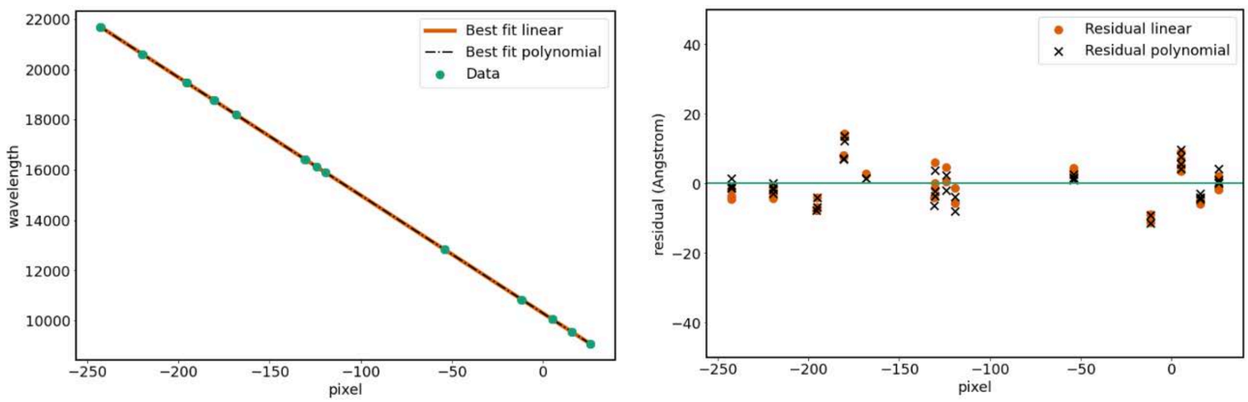


Figure 4. Wavelength solution fit (left) and residuals (right) for GR150R for order 1 in the subarray.

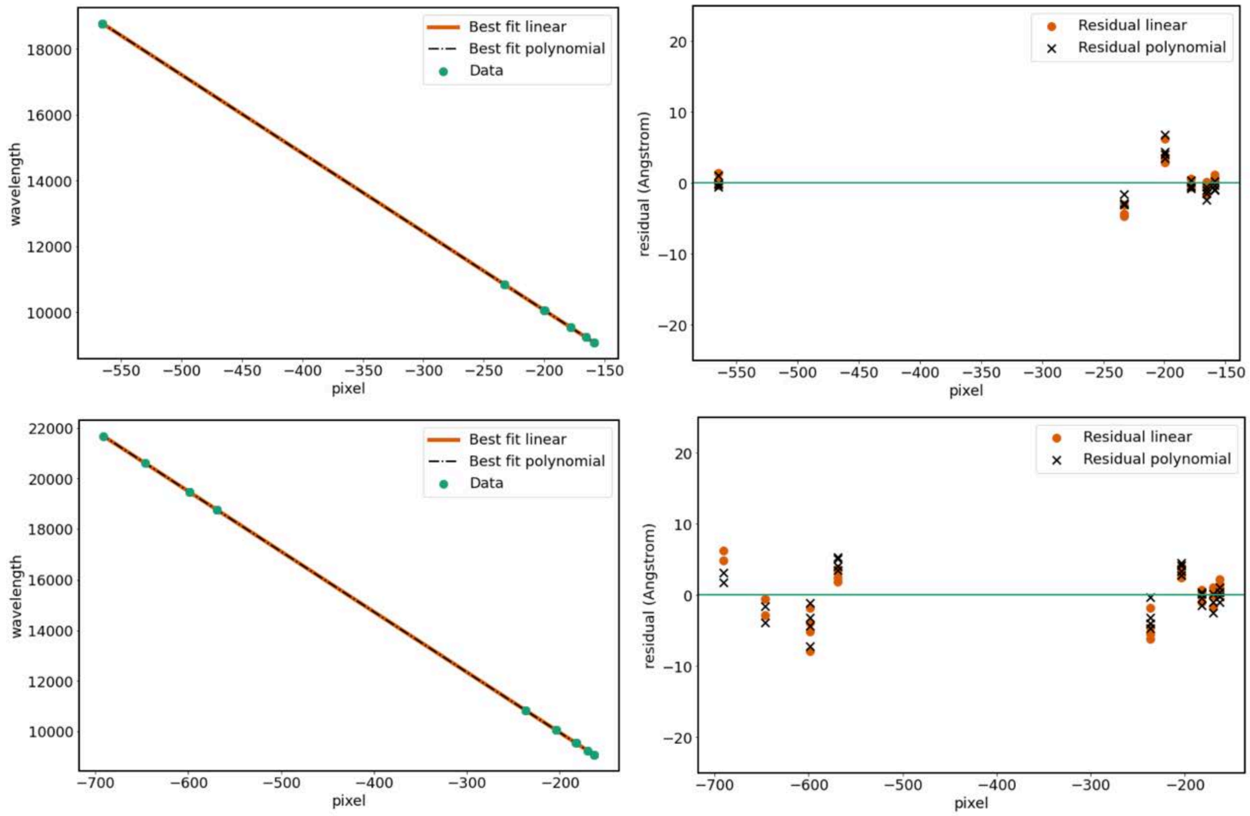


Figure 5. Top: wavelength solution fit (left) and residuals (right) for GR150C for order 2; the spectrum in F200W/GR150C was contaminated by another trace and only one emission line could be detected. Bottom: wavelength solution fit (left) and residuals (right) for GR150R for order 2.

Figure 6, 7, and 8 show the comparison of the calibrated spectra with the model spectrum at matching resolution for order 1 in full frame, order 1 in the subarray, and order 2 in full frame, respectively. Flux calibration has not been applied for this analysis, thus the line strengths and ratios do not match those in the model spectrum. The order 2 of F158M and F150W could not be detected. We estimated their position for the extraction, but they were not used for the analysis. The order 2 spectrum of F200W in GR150C was contaminated by another trace and only one emission line could be detected and used.

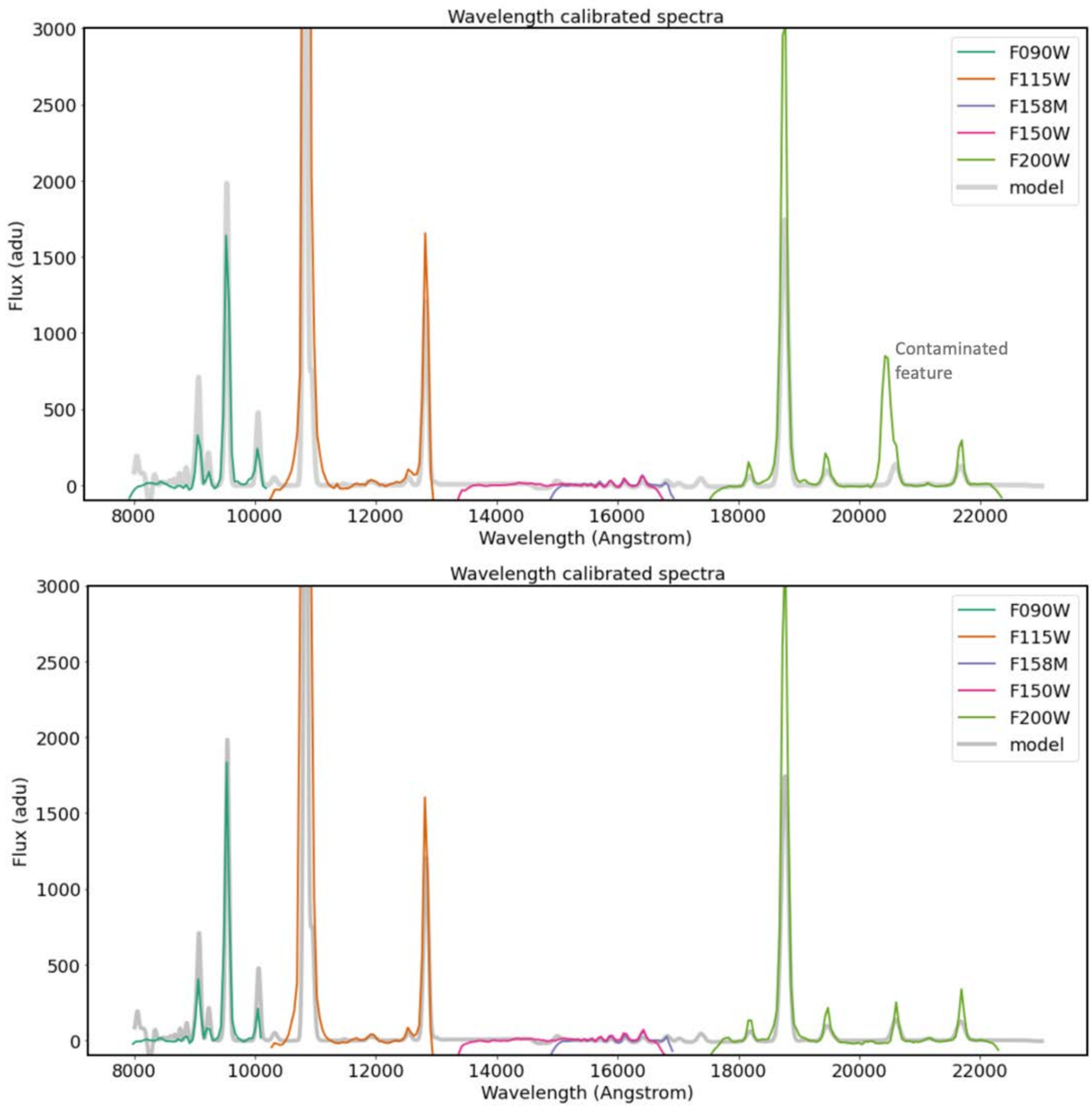


Figure 6. Wavelength calibrated spectra and model spectrum for GR150C (top) and GR150R (bottom) in full frame for order 1.

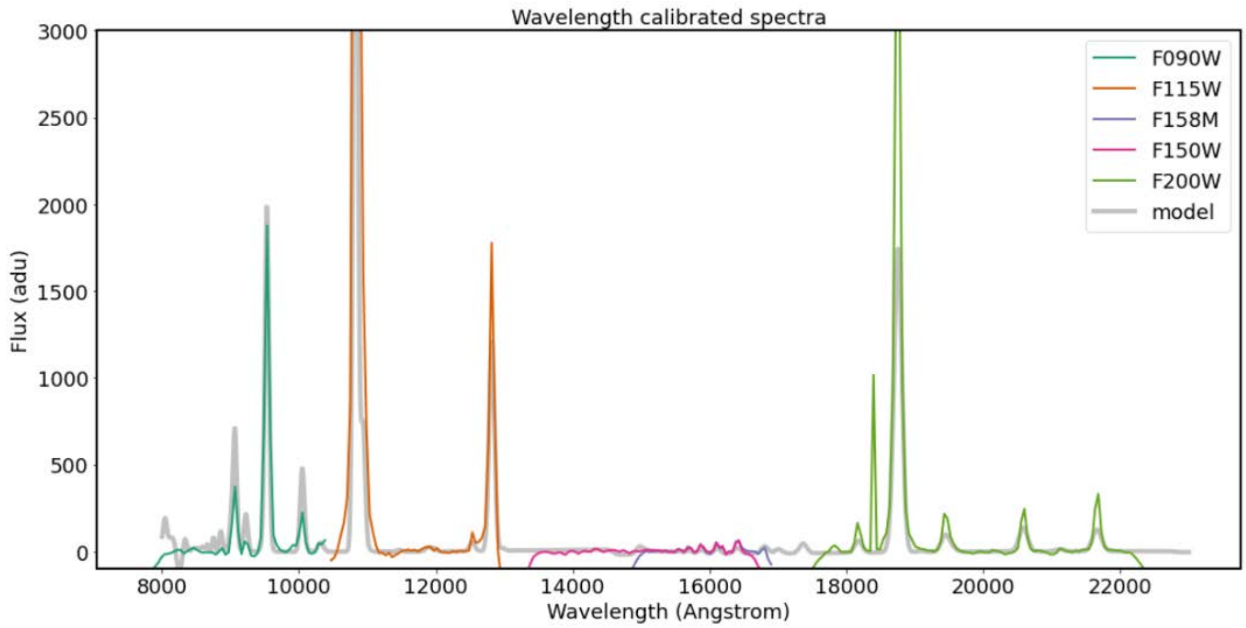


Figure 7. Wavelength calibrated spectra and model spectrum for GR150R in subarray for order 1.

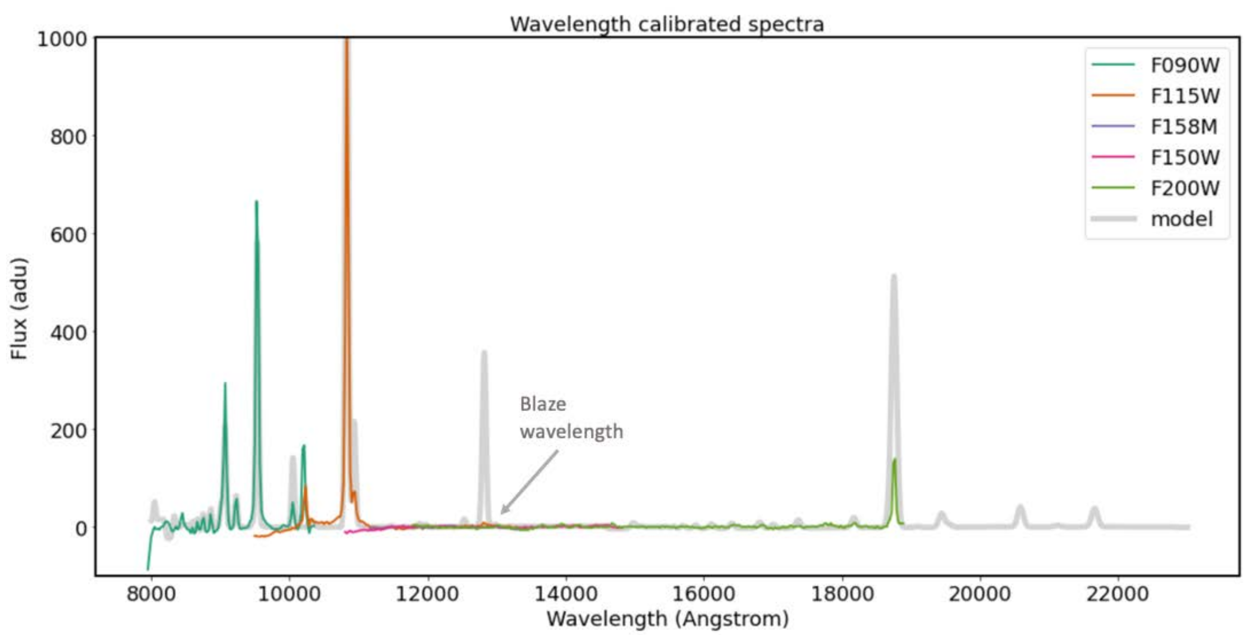


Figure 8.1 Wavelength calibrated spectra and model spectrum for GR150C in full frame for order 2. The spectrum in F200W was contaminated by another trace and only one emission line could be detected.

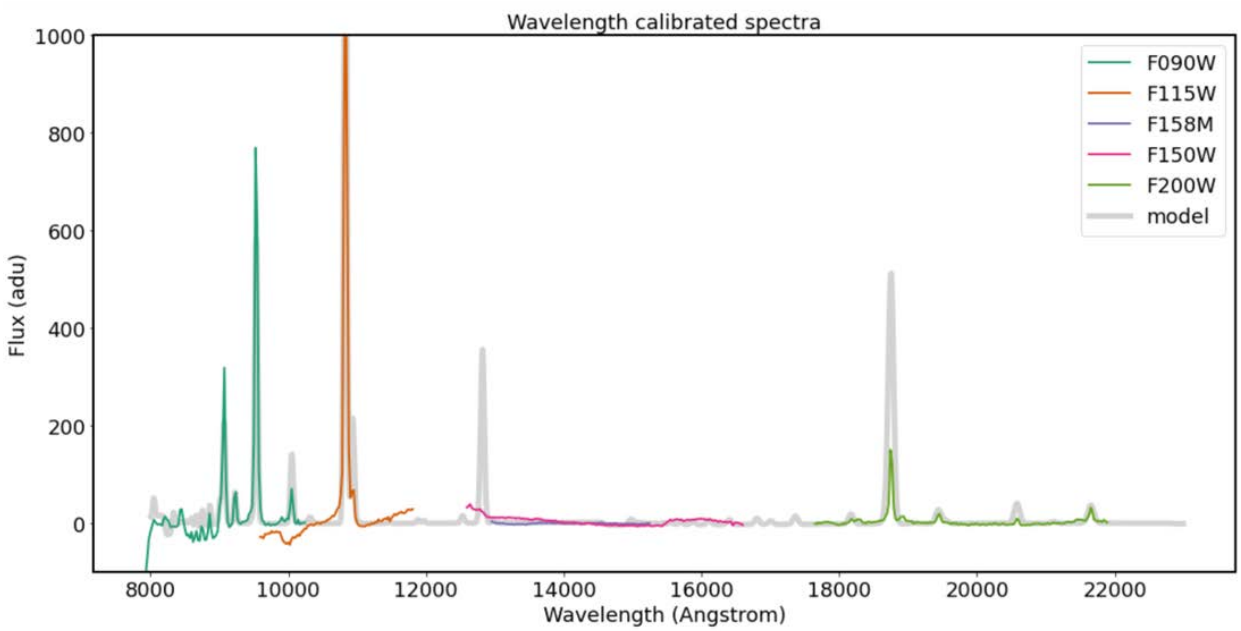


Figure 8.2 Wavelength calibrated spectra and model spectrum for GR150R in full frame for order 2

6 Conclusion

The GR150C and GR150R grisms are healthy and the wavelength dispersions of order 1 (47.015 Å/pix for GR150C and 46.939 Å/pix for GR150R) and order 2 (23.864 Å/pix for GR150C and 23.859 Å/pix for GR150R) match the calibration derived in ground testing. In this CAR, we have measured the wavelength calibration for both grisms for orders 1 and 2 in the center of the field. The calibration in the corners will be done as part of the Cycle 1 calibration program. The *specwcs* reference files have been updated and delivered for use with all the Cycle 1 programs.

7 References

Ferland G. J., 1996, in Ferland G. J., ed., Hazy, A Brief Introduction to Cloudy 90. Internal Report, Univ. Kentucky, Lexington

Martel, A.R. 2021, The Commissioning of the Near-Infrared Imager and Slitless Spectrograph (NIRISS), JWST-STScI-006771 (Baltimore: STScI)

Ravindranath, S. 2014, NIRISS GR150R and GR150C Grism Calibration – Wavelength Calibration, JWST-STScI- 003781 (Baltimore: STScI)