Updated Calibration and Backgrounds for the WFC3 IR Grisms

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ABSTRACT

We present new and improved calibration of the WFC IR (G102 and G141) grism mode. These new calibrations were generated by combining data obtained over six observing cycles and include a better sampling of the calibrator targets across the field of view. The result is a calibration of the spectral trace that has been improved to better than 0.1 detector pixel. A new fiducial wavelength reference spectrum is now used to calibrate the wavelength dispersion of the grisms and we show that the RMS of the solution has been reduced to approximately 7 and 14 Angstrom for the G102 and G141 grisms, over the entire field of view. Overall, both the trace and wavelength calibration have been improved by about a factor of two and the G102 and G141 solutions are in better agreement at wavelengths where the two grisms overlap. We demonstrate that the grism calibration can be extrapolated for objects that are outside of the field of view but still result in dispersed spectra on the WFC3 detector.
We also present new master sky images that can be used to improve the sky background subtraction from grism exposures. The individual components of the new background model include the zodiacal continuum and a strong He I emission line at 1.083 microns from the upper atmosphere. We find that fitting science exposures with a linear combination of these two background components enables modeling of the WFC3/IR grism background with an accuracy that is better than ~0.01 electrons/s/pix across the detector.

SPECTRAL CALIBRATION

- Existing calibrations (V. 2.x) are based on a limited number of positions in the field-of-view and wavelength calibration is based on a reference spectrum of VY2-2 which does not reach below 11500A and the observed 10830/10938 HeI/Pγ ratio does not match this reference spectrum (Bohlin et al.).
- New calibrations (V. 3.x) are based on 25 positions over the entire detector and the wavelength calibration is based on a high resolution spectrum of IC5117 (Rudy et al. 2001), another PN with excitation levels similar to VY2-2 which agrees well with the observations.
- New calibrations (V. 3.x) are based on a new calibration paradigm to solve the field dependence of the spectral traces and spectral wavelength dispersions.

GRISM BACKGROUNDS

- A new set of Grism background were derived.
- The G102 and G141 background solution now includes two components: A Zodiacal component (similar to the existing one) and a HeI component.
- The two background components, available for both G102 and G141, have different stuctures. When appropriatly subtracted from observed FLT files, with on-the-ramp fitting disabled, background residuals are as low as 0.1 e-/s/pixel.

NEW CALIBRATION PARADIGM

- aXe required polynomial descriptions of both the spectral trace (where the spectrum is wrt the object in the FOV) and of the wavelength solution (to wavelength calibrate things)

$$dy = a_1 \times dx + a_2 \times dx^2 + ... + a_n \times dx^n$$

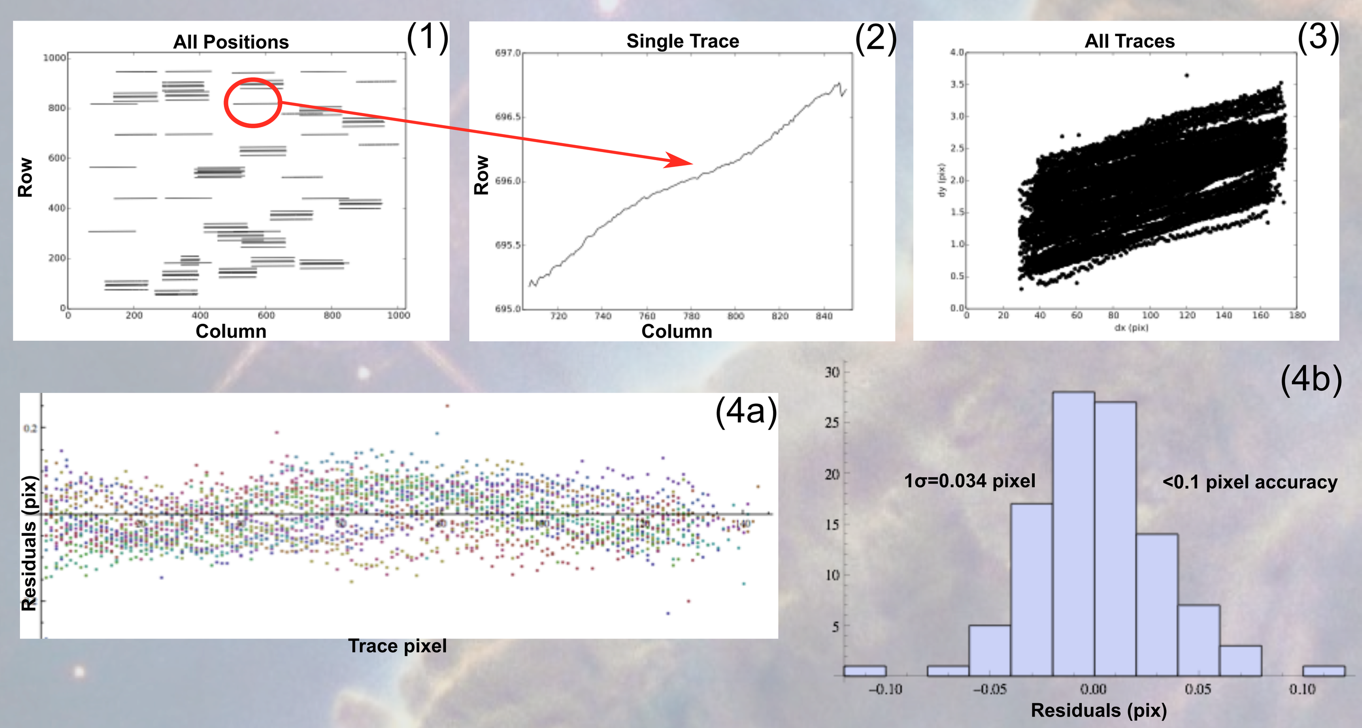
- aXe also requires a 2D polynomial description for the field dependence.

$$a1 = b_1 + b_2 \times i + b_3 \times j + b_4 \times i^2 + b_5 \times ij + b_6 \times j^2$$

- Traditionally first fitted the spectra at each observed positions and then fitted each individual coefficients to a 2D polynomial
- Now, we fit everything at once... solving for 12 variables at once for a simple linear trace with a 2nd order 2D field dependence:

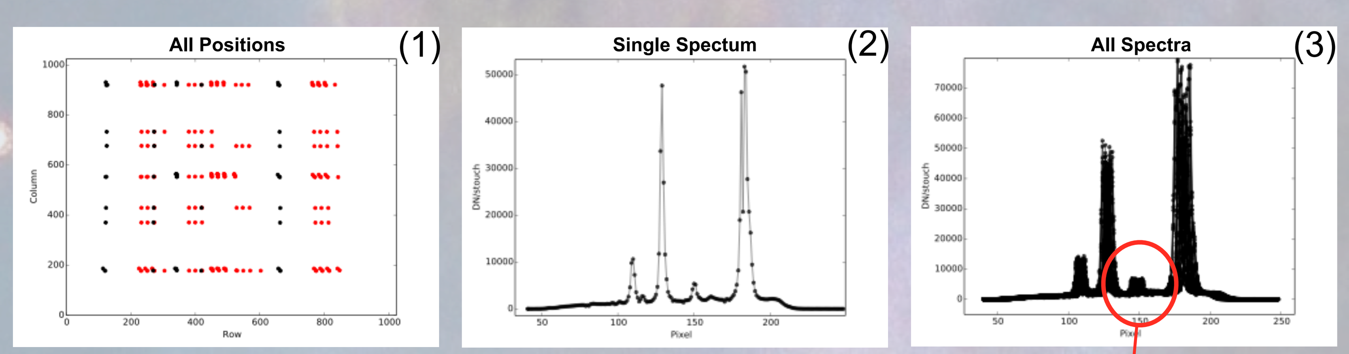
$$dy(x,y,dx) = e_{0,0} + xe_{0,1} + x^2e_{0,3} + xye_{0,4} + y^2e_{0,5} + dx(e_{1,0} + xe_{1,1} + ye_{1,2} + x^2e_{1,3} + xye_{1,4} + y^2e_{1,5})$$

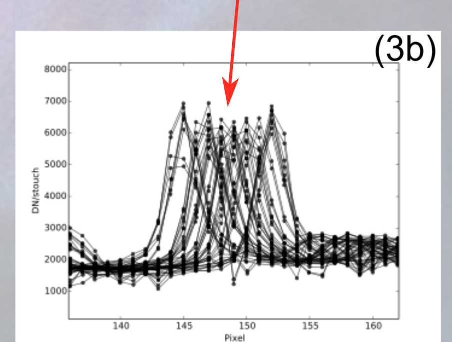
G102 TRACE CALIBRATION



- These panels illustrate the large field dependence of the grism traces over the field of view (Panels 1-3).
- The residuals of the spectra traces are now calibrated to better than 0.1 pixel, as shown in Panels 4a and 4b.

G102 WAVELENGTH CALIBRATION

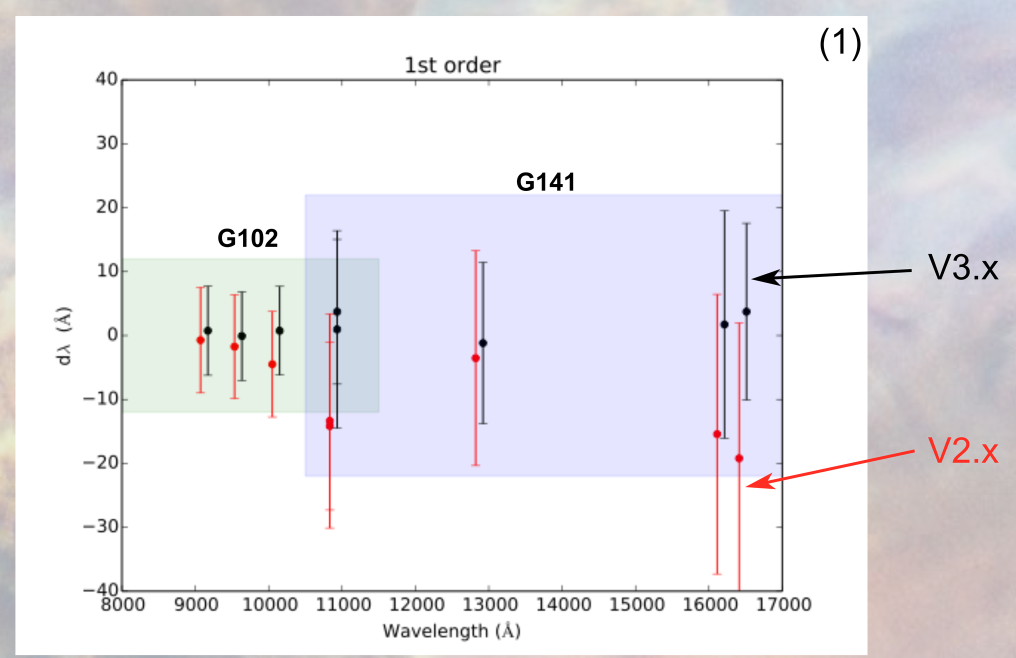


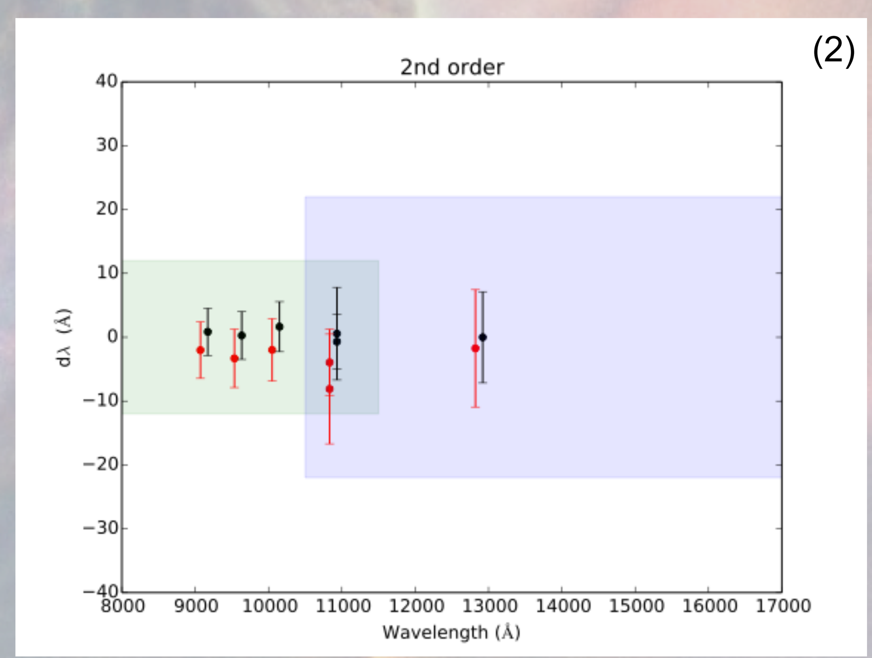


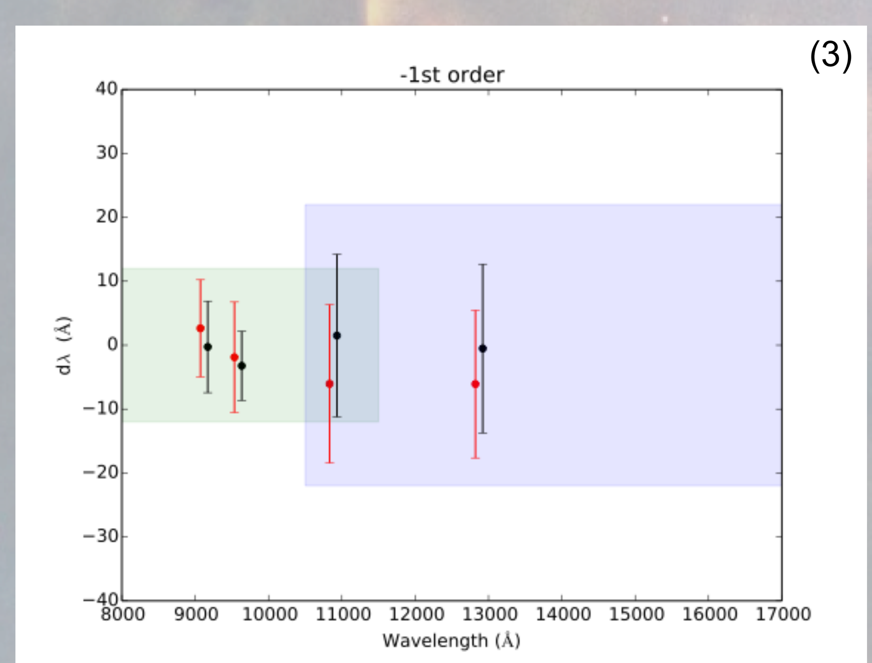
- The field dependence of the wavelegnth solution is shown here.
- Panel 1 shows the object positions (black) and the VY2-2 emission lines (red)
- A single spectrum is shown in Panel 2 while panels 3 and 3b illustrate the large change in dispersion as a function of position.

V3.X GRISM CALIBRATION SUMMARY

- The following panels shown the agreement between the fiducial and measured wavelengths of the VY2-2 emission lines for the G102 grism (light green area) and G141 grism (light blue area). We show the previous claibration (V2.x) in red and the new calibrations (V3.x) in black. The following panels show:
  - 1) The agreement between the G102 and G141 grism is now significantly improved
  - 2) Deviation between fidicial and measured emission line wavelengths is now better than 7A with G102 and 14A with G141 (Panel 1).
  - The -1 and 2nd spectral were also recalibrated and are now consistent with the 1st order both in the G102 and G141 grisms

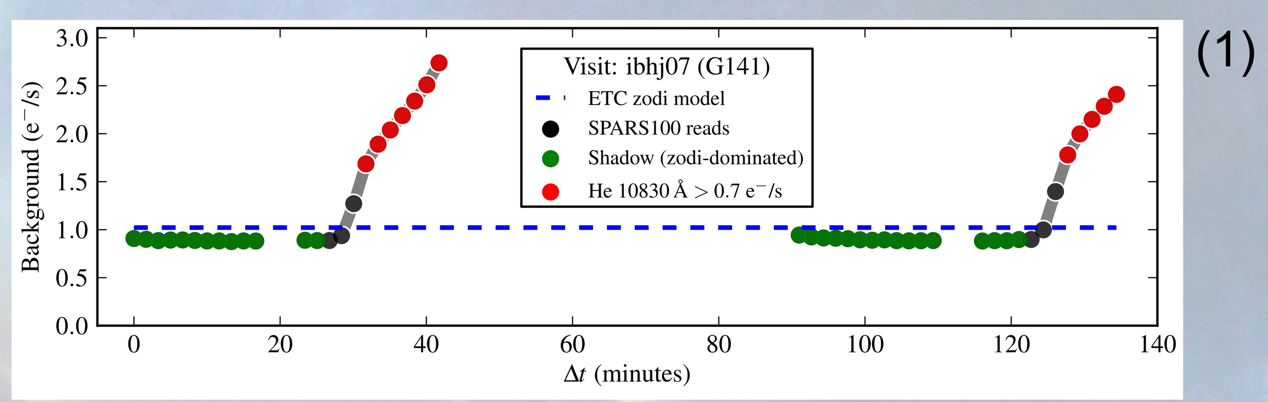




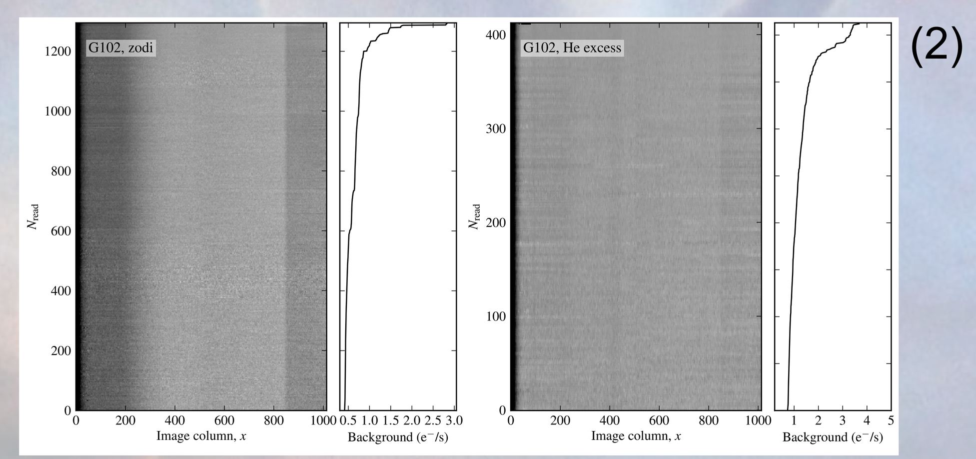


IR GRISM MASTER BACKGROUNDS

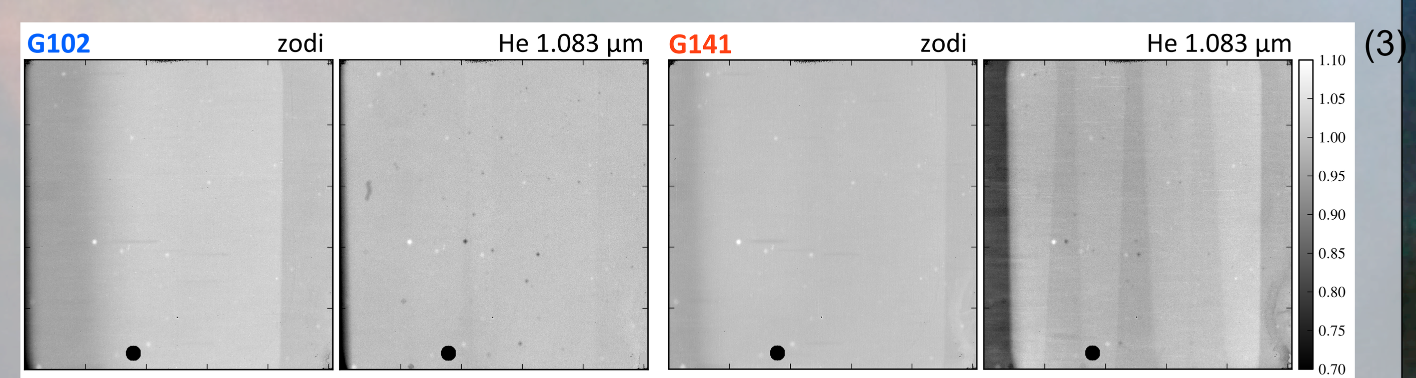
The IR background can vary duing the course of an observation, as shown Panel 1. This is caused primarily by He I emission at 1.083 μm from the sunlit upper Earth atmosphere (see WFC3 ISR 2014-03). This emission is seen in the F105W, F110W filters and both grisms on the day-time part of HST's orbit and is negligible when the spacecraft is in the Earth shadow. The current version of the aXe grism reduction software fits a single-component background model determined from archival observations obtained in the first years after WFC3 was installed. However, in the presence of time-variable backgrounds, we find that a multi-component model is needed in order to properly model and subtract the grism sky background.



Panel 1: Background countrate for four G141 exposures from visit ibhj07 (GO-12177). Individual 100 s reads from the SPARS100 sample sequence are shown with the large symbols. Reads taken with the telescope in the Earth shadow are shown in green, where the background is dominated by zodiacal light. The dashed blue line shows the zodi prediction from the WFC3 ETC for the specific epoch and target coordinates of the observations. Reads where the additional background arising from the He 1.083 μm emission line exceeds 0.7 e-/s are shown in red.



Panel 2: Object-masked, column-averaged G102 background profiles for individual SPARS100 reads dominated by zodiacal light (left) and for reads with a significant contribution from the He 1.083 μm line (right). The rows are sorted following the observed background countrate of the reads, which is plotted next to the image panels. The zodiacal continuum and He emission-line backgrounds result in distinct background profiles, but once the components are separated, the background structure is very uniform across many exposures and programs.



Panel 3: Master zodi and He background images for the G102 grism. The negative IR blob spectra clearly demonstrate the clean separation of the zodiacal continuum and He 1.083 μm emission-line components of the background. The background in a given grism exposure not taken entirely within the Earth shadow, such as those shown in Fig. 1, will be a linear combination of these two separable components.