Exposure Time Calculator Step-by-Step Guide for NIRISS WFSS

Science Goals

- Determine exposure parameters for a NIRISS WFSS program to observe a field of galaxies
  - Define representative sources in ETC to estimate reasonable exposure parameters
- How long should the direct image exposures be to detect faint sources in the field?
  - Define a source with a faint magnitude so that if a source at that brightness limit is in the field, we can be confident we would detect it at the 5σ level with our exposure parameters.
- How long should the grism exposures be to characterize the spectral properties of the detected galaxies?
  - Use a template for the type of galaxy we hope to detect in the field so that we choose exposure parameters to detect spectral lines at a given significance to diagnose physical properties of the source. For this case, we use the Spectral Energy distribution of a known star-forming galaxy/AGN composite (provided by the ETC) for illustrative purposes. User-supplied templates can also be uploaded, which may be more appropriate for your science.

Science Goals – Derive Exposure Parameters to Achieve:

- Direct image:
  - Sensitivity z = 28 (AB) 5σ in F200W filter
- Grism spectroscopy
  - SNR = 10/pixel for:
    - [OIII] + continuum (F150W filter)
    - Hα + continuum (F200W filter)

Operational considerations for setting up NIRISS WFSS observations

- Use both GR150R and GR150C grisms to disperse light orthogonally to mitigate contamination from overlapping spectra
  - In this ETC exercise, we show calculations for 1 grism, and will apply the same exposure parameters to both grisms
  - In the APT, we'll ensure that "BOTH" grisms are chosen in the NIRISS WFSS observation template
- # of dither steps is balance between efficiency, PSF sampling, & depth considerations. For illustrative purposes, we assume 6 dither steps.

https://jwst-docs.stsci.edu/near-infrared-imager-and-slitless-spectrograph/niriss-observing-strategies/niriss-wfss-recommended-strategies

Setting up the scene & defining galaxy properties

- Rename scene “WFSS Scene”
- Rename source “SF/AGN Composite”
- Define SF/AGN Composite Properties:
  - *Continuum*
    - Spectral Energy Distribution: Galaxy Spectra → NGC 5953 (Sa; SF/AGN)
    - Redshift: 2
  - *Renorm*
    - Normalize in bandpass: K = 21 (Vega)
  - *Shape*: point
  - *Offset*: none
- Visualize spectrum in NIRISS WFSS bandpass (0.8 – 2.2 μm)
  - [OIII] ~ 1.5 μm (F150W filter)
  - Hα ~ 1.97 μm (F200W filter)

Add faint source to scene & define its properties

- Add source to WFSS scene
- Rename source “Faint Galaxy”
- Define Faint Galaxy Properties:
  - *Continuum*
    - Spectral Energy Distribution: Flat continuum
  - *Renorm*
    - Normalize in bandpass: SDSS *z* = 28 (AB)
  - *Shape*: point
  - *Offset*
    - X offset: 1 (arcsec)
    - Y offset: 1.2 (arcsec)

Calculation: Detect Faint Galaxy at SNR = 5 in Direct Imaging (1/2)

- Recall:
  - 1 direct image prior to *each* set of dithered grism exposures for NIRISS WFSS
  - Both grisms recommended for crowded fields

  ==> 4 direct images for each filter
- Initialize NIRISS Imaging Calculation in F200W filter
- ***Strategy***
  - **Centered on source**: 2: Faint Galaxy
  - Keep aperture radius and background sky annulus radii at default: optimized for F200W filter (80% encircled energy radius for aperture; 2x & 4x extraction radius for background)

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Calculation: Detect Faint Galaxy at SNR = 5 in Direct Imaging (2/2)

- *Detector Setup*
  - Subarray: Full (only option available for imaging)
  - Readout pattern: NIS (preferred for deeper observations)
  - Groups per integration: 10 (ETC default; will adjust later)
  - Integrations per exposure: 1 (ETC default)
  - Exposures per specification: 4 *(total number of direct images per set of grism exposures)*

    ==> SNR ~ 5.6
- Find # of groups where SNR = 5 via **Batch Expansion**
  - Expand --> Expand Groups
    - Start Value = 7
    - Step Size = 1
    - Iterations = 3

    ==> Groups per integration = 8, SNR ~ 5

    use Number of Groups = 8 for APT template

Calculation: Detect [OIII] + Continuum at SNR = 10/pixel in Grism Exposure (1/3)

- Recall:
  - [OIII] in F150W filter
  - 6 dither steps for this program
- Initialize NIRISS WFSS Calculation
- *Instrument Setup*
  - Filter: update to F150W
  - Need to update wavelength of interest in *Strategy* tab
    - Note, midpoint of filter (1.5 μm) is observed wavelength of [OIII]

Calculation: Detect [OIII] + Continuum at SNR = 10/pixel in Grism Exposure (2/3)

- *Detector Setup*
  - *Pro tip: Mimic # of dithers in ETC with # of "Exposures per specification"*
  - Subarray: Full (only option available for imaging)
  - Readout pattern: NIS (preferred for deeper observations)
  - Groups per integration: 10 (ETC default; will adjust later)
  - Integrations per exposure: 1 (ETC default)
  - Exposures per specification: 6
- *Strategy*
  - Centered on source: 1: SF/AGN Composite
  - Aperture half-height: 0.185" (80% encircled energy radius for point source in F150W)
  - Sky sample start region: 0.37"
  - Sky sample end region: 0.74"

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Calculation: Detect [OIII] + Continuum at SNR = 10/pixel in Grism Exposure (3/3)

- SNR ~ 7 for initial calculation
- **Batch expansion**
  - Expand --> Expand Groups
    - Start Value = 20
    - Step Size = 1
    - Iterations = 3

==> Groups per integration = 21, SNR ~ 10

use Number of Groups = 21 for APT template

Calculation: Detect Hα + Continuum at SNR = 10/pixel in Grism Exposure (1/3)

- Recall:
  - [OIII] in F200W filter
  - 6 dither steps for this program
- Initialize NIRISS WFSS Calculation
- *Instrument Setup*
  - Filter: update to F200W
  - Need to update wavelength of interest in *Strategy* tab
    - Update to observed wavelength of Hα at this redshift (λ = 1.97 μm)

Calculation: Detect Hα + Continuum at SNR = 10/pixel in Grism Exposure (2/3)

- *Detector Setup*
  - Subarray: Full (only option available for imaging)
  - Readout pattern: NIS (preferred for deeper observations)
  - Groups per integration: 10 (ETC default; will adjust later)
  - Integrations per exposure: 1 (ETC default)
  - Exposures per specification: **6 (*for 6 step dither pattern)***
- *Strategy*
  - Centered on source: 1: SF/AGN Composite
  - Aperture half-height: 0.185” (80% encircled energy radius for point source in F150W)
  - Sky sample start region: 0.37”
  - Sky sample end region: 0.74”

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Calculation: Detect Hα + Continuum at SNR = 10/pixel in Grism Exposure (3/3)

- SNR ~ 13 for initial calculation
- **Batch expansion**
  - Expand --> Expand Groups
    - Start Value = 6
    - Step Size = 1
    - Iterations = 3

==> Groups per integration = 7, SNR ~ 10

use Number of Groups = 7 for APT template

ETC exposure parameters to input into APT

- Filters: F150W & F200W
- NIS readout pattern (for both direct imaging & grism observations)
- Direct Image:
  - # of Groups = 8
  - # of Integrations = 1
- Grism observations:
  - # of dithers = 6
  - F150W
    - # of Groups = 21
    - # of Integrations = 1
  - F200W
    - # of Groups = 7
    - # of Integrations = 1