Imaging Hands-On

1. Introduction

Located at a redshift of z=0.018, Arp 220 is the nearest ULIRG (Ultra-Luminous Infrared Galaxy). In this exercise, you will put together a (simplified) proposal to study its unresolved emission (in terms of not resolving individual stars). NIR imaging with NIRCam can be used to perform accurate multi-component galaxy model fitting and also measure surface brightness fluctuations and radial stellar populations gradients. Mid-IR observations with MIRI can detect the presence of a significant intermediate-age component or warm ISM.
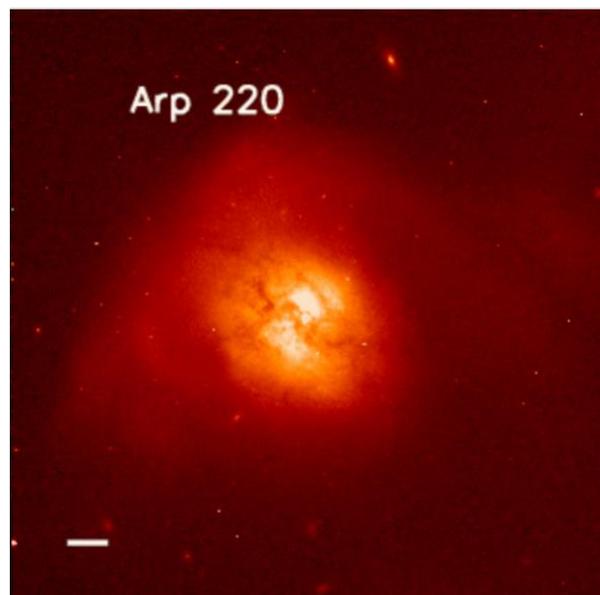

Figure 1: Arp 220 observed with HST (WFPC2/F814). The horizontal bar indicates 5 arcseconds.

2. Instruments configurations

Before deciding the instrument configurations, users must consider their science case and the optimized way of using the instruments.

- NIRCam:
  - Filters: F090W (for stellar studies) and F335M for PAHs studies.
  - Subarray: SUB640 (Arp220 is small and fits well in this 20.5"x20.5" subarray).
  - Readout mode: RAPID (always run the ETC to finally decide this).

- MIRI:
  - Filter: F770W broad band imaging to trace dust and PAHs.

- Subarray: BRIGHTSKY (need to run the ETC to evaluate saturation levels).
- Readout mode: FAST.

Find more details about subarrays and readout modes in the reference links at the end of this document.

3. Exposure Time Calculator

Objective: In this section, you will find detailed instructions to create an ETC workbook that estimates the time required to achieve the proposed scientific goals. The objective is to reach SNR per pixel > 150 in all cases.

If this section takes too long, go to the workbook specified above to find the answers; later on, feel free to copy it and play around with all the options. You might even find a better way of modelling this science case!

a. Getting Started

Go to the ETC and create/load a new workbook.

b. Scenes and sources
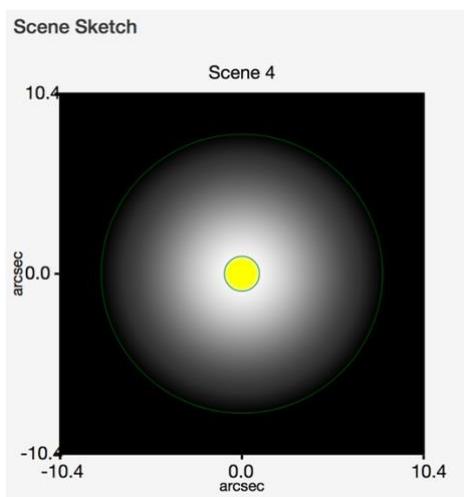
We will model Arp220 using two different sources:

Figure 2: Arp 220 scene sketch as produced by the JWST ETC using sources proposed in this exercise.

1. **Source 1:**
   a. Create a new source in the Source Editor on the right-hand side of the ETC.
   b. In the continuum tab select Galaxy Spectra from Brown and the IC4553/Arp220 spectrum. Do not renormalize it (the template is from this same target).
   c. Define an extended source in the shape tab and assign a profile and size. Arp220 is small and the peak in its molecular gas surface density is at radii less than 0.5 kpc. We will model Arp220 with a Sersic (scale radius) profile and a 1 arcsec semi- major and minor axis.

2. **Source 2:** This will represent the more extended diffuse emission.
   a. Create a new source
   b. Define a flat continuum and renormalize it to 28 AB mag, Johnson V. Model the source as a 2D Gaussian with 8 arcsec semi-major and semi-minor axes.

Create a scene that combines the two defined sources (see Figure 2).

c. Calculations

For each individual filter, you will need one calculation. Go to the calculations tab on the left and create entries for each of the relevant observing modes: MIRI Imaging, NIRCam SW Imaging and NIRCam LW Imaging. In this example, we will observe with the NIRCam short and long wavelength filter pairs simultaneously (in this case F090W and F335M) and thus they need the same number of groups and integrations per exposure.

The following steps should be repeated for each individual calculation. To work in a calculation, make sure it is highlighted in yellow.
a. Under the instrument setup tab on the right, pick the relevant filter.
b. Go to the detector setup tab and select the readout mode and subarray.
c. Under the strategy tab select the background region using the following parameters: aperture location centered on source, aperture radius 0.2 arcsec. This small radius is chosen to measure the radial stellar flux gradient. Select the "noiseless sky background" to subtract the count rate corresponding to the sky background chosen in the Backgrounds tab. In this case the contamination from within the scene is not subtracted from the extracted source flux.
d. In the background tab there are several standard choices. In this example, we will use "Low". Feel free to test the others to evaluate the impact in your calculations.
e. Go back to the detector setup tab and configure your observations. Select a number of groups per integrations, integrations per exposure and exposures to reach a SNR per pixel > 150 in all cases. Evaluate the SNR in the bottom panels of the ETC. *Hint: use 4 exposures for MIRI and 9 for NIRCam. These are the number of dithers we will use in APT later.*
f. The number of exposures in the ETC are equivalent to the number of dithers or exposures in APT. This assumes the coverage achieved through dithers is even. Remember that mosaics and dithers will likely not yield 100% redundancy in all pixels, thus the ETC SNR estimation will not apply all over the FOV.
g. Note that this is an iterative process; as mentioned in the slides the choice of dither patterns is key and will impact the ETC calculations.

4. Astronomer's Proposal Tool

Objective: In this section, you will work with the Astronomer's Proposal Tool (APT) to get this combined MIRI-NIRCam proposal "submission ready".
1. Open APT and create a new JWST proposal.
2. Go to the target section and select the "fixed target resolver" option. Search for Arp220 and select the object as target.
3. This program uses two instruments as "prime" so you will need two different observation folders: one for MIRI and one for NIRCam. Name the folders accordingly.
4. In each folder, select the corresponding instrument, template and target.
5. Select the desired dither pattern for each observation. Here are some suggestions:
   a. MIRI: 4-point sets (extended source), 1 set, starting set 6.
   b. NIRCam: INTRASCA, 3 primary dithers, dither size SMALL, subpixel positions 3.
6. Select the filter, readout pattern, number of groups per integration and integrations per exposure used in the ETC. Make sure to select one exposure per dither position. The total exposure time should match that of the ETC.
7. Use Aladin (icon at the top of the APT window) to verify the spatial coverage provided by the selected subarray/dither combination. Check the effect of different orientations will have on the coverage.

8. If needed define a mosaic to cover the main body of Arp220. Make sure to check the impact of different orientations on the coverage. For MIRI, does your mosaic give you a measure of the sky/background? *Hint: a 2x1 mosaic could help to get sky+background information. Check these recommendations on JDox.* [*https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-observing-strategies/miri-cross-mode-recommended-strategies#MIRICross-ModeRecommendedStrategies-MIRIbackgroundBackgroundobservationsrecommendations*](https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-observing-strategies/miri-cross-mode-recommended-strategies#MIRICross-ModeRecommendedStrategies-MIRIbackgroundBackgroundobservationsrecommendations)

4.1 Standard APT checks

a) Data volume considerations: Are the individual visits running into data volume warning issues? If so, what is the possible solution?
b) Special requirements: Do you need to impose any (scientifically justified) time or position angle (PA) constraint?
c) Visit planner (select the observation first): Verify that the program is schedulable, and run smart accounting to remove unnecessary overheads. Does APT issue any error or warning? The total program time can be seen in the Proposal Information Pane of APT.

5. Reference links

MIRI
https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-instrumentation/miri-detector-overview/miri-detector-readout-overview
https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-instrumentation/miri-detector-overview/miri-detector-subarrays
https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-operations/miri-dithering/miri-imaging-dithering
https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-operations/miri-mosaics/miri-imaging-mosaics
https://jwst-docs.stsci.edu/mid-infrared-instrument/miri-observing-strategies/miri-imaging-recommended-strategies

NIRCam
https://jwst-docs.stsci.edu/near-infrared-camera/nircam-instrumentation/nircam-detector-overview/nircam-detector-readout-patterns
https://jwst-docs.stsci.edu/near-infrared-camera/nircam-instrumentation/nircam-detector-overview/nircam-detector-subarrays
https://jwst-docs.stsci.edu/near-infrared-camera/nircam-operations/nircam-dithers-and-mosaics
https://jwst-docs.stsci.edu/near-infrared-camera/nircam-operations/nircam-dithers-and-mosaics/nircam-subpixel-dithers
https://jwst-docs.stsci.edu/near-infrared-camera/nircam-observing-strategies/nircam-imaging-recommended-strategies