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TECHNICAL REPORT

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Title: Science Use-Cases for the Preparation of Coronagraphic Operations Concepts and Policies	Doc #: JWST-STScI-004140, SM-12 Date: April 1, 2015 Rev: -
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1 Abstract

This technical report describes a set of science use-cases for coronagraphic observations with the JWST coronagraphs (NIRCam and MIRI). The Coronagraphs Working Group (CWG) established these use-cases to be representative of the type of science programs that are expected at this time with JWST coronagraphic modes. It is important to note that these use-cases are not intended to define a science program with the JWST coronagraphs. The goal of this report is to provide a reference to guide the development of the systems supporting coronagraphic operations at the Science and Operations Center (S&OC), which are detailed in a series of technical reports describing the coronagraphic operations concepts listed below. At the date of this technical report it was determined that the super-template will not be available until Cycle 2. Further work will be needed to established the feasibility of these science cases with the current version of APT.

- [TR1] Science Use-Cases for the Preparation of Coronagraphic Operations Concepts and Policies JWST-STScI-004140 (this report)
- [TR2] Coronagraphic Operations Concepts and Super-Template Definition for the Astronomer's Proposal Tool JWST-STScI-004141
- [TR3] Comparative study of the efficiency of various coronagraphic observations strategies JWST-STScI-004165
- [TR4] Coronagraphic Exposure Time Calculation JWST-STScI-003862
- [TR5] Coronagraphic Astrometric and Photometric Calibrations JWST-STScI-004166
- [TR6] A Point Spread Functions Library for Coronagraphy JWST-STScI-004167

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- [TR7] Coronagraphic pipeline architecture, data products JWST-STScI-004169
- [TR8] Coronagraphic pipeline algorithms JWST-STScI- 004170
- [TR9] Small-Grid Dithers for Coronagraphic Observations JWST-STScI-004142 and JWST-STScI-004172
- [TR10] Coronagraphic policies JWST-STScI-004171

2 Introduction

The science use-cases in this report were ranked in order of scientific importance by the CWG. The first seven use-cases are expected to represent the vast majority of JWST coronagraphic observations, and therefore should be used to establish the requirements for the S&OC systems (APT, ETC, Pipeline, etc.). The last use-case completes the set of plausible utilizations for the coronagraphs but is not expected to drive any requirements for operations. However it is desirable that chosen implementations remain broadly compatible with more unusual proposals (e.g. that the pipeline does not crash if presented with these data, or that APT allows a "manual" mode to edit the observations directly and allow for more unusual use-cases). The use-cases in this document are presented from the point of view of the science proposal and the user with their implications on templates, ETC, pipeline and policies. The use-cases are:

- Characterization of a known planet
- Characterization of a known disk
- Self-referenced survey a several targets
- Shared-reference survey
- Easy targets
- Observations at the limit of capabilities
- Faint target/ extragalactic observations
- Unconventional observations

3 Definitions and Assumptions

This document assumes the existence of a super-template in APT where the observer can define the high-level implementation of the proposal (e.g. targets and reference stars, filters, types of rolls, optional small-grid dithers). The super-template generates the proposal's observations with appropriate special requirements (e.g. rolls, back-to-back scheduling where appropriate). Then the observer edits specific fields inside the template form for each observation at the instrument level (one template form for each instrument NIRCam and MIRI). The details of the super-template concepts are discussed in [TR2].

The following are some important terms and concepts used herein and in the other technical reports listed in the abstract.

- ***Coronagraphic Sequence***: a set of observations for a single science target and assembled in an observation folder. The coronagraphic sequence combines observations of the target itself, possibly with a ~+/- 5 deg telescope roll (see [TR2] for details on the rolls), associated reference star(s), or optional small-grid dithers (see [TR2] and [TR9] for details on small-grid dithers). The *basic coronagraphic*

sequence is: target, +/- 5 deg roll on target, and reference star. More complex *coronagraphic sequences* can be assembled and customized by the user, for example involving observations with both MIRI and NIRCam coronagraphs. While non-standard sequences are technically possible by editing manually the observations, they require additional justification submitted to the TAC. Because the PSF will vary with time from wavefront thermal evolution we assume that reference PSFs and science observations must be sequenced back to back. By definition a coronagraphic sequence is non-interruptible for scheduling purposes (aka "sequence NON-INT" by Commanding).

- ***Coronagraphic Suite:*** an ensemble of coronagraphic sequences for several (identical or different) science targets. A suite can include *basic coronagraphic sequences*, or more complex ones (e.g. with optional observations such as small-grid dithers). Standard coronagraphic suites also include two particular sub-types: the *Self-Referenced Suite* and the *Shared-Reference Suite*.
- ***Coronagraphic Template Form***: the APT form that is used for coronagraphic observations, and applies to a particular instrument (NIRCam and MIRI). The same form is invoked for target, references or rolled targets.
- ***Coronagraphic Super Template Form:*** The APT form that is used to assemble coronagraphic sequences (either basic or more complex) into a coronagraphic suite. The super-template detects standard and non-standard uses of the coronagraphs.
- ***Small-Grid Dither:*** an optional technique which adds dithered positions on the reference PSF, under closed-loop fine guidance; The dither pattern is square grid of 5 or 9 points, of step 10 mas. The SGD technique will be mostly useful for MIRI and are also applicable for NIRCam but to a lesser effect (to be evaluated at this time)
- ***Reference PSF library:*** a database of coronagraphic reference PSFs, accumulated from all coronagraphic programs

4 Possible Science Use-cases for the JWST coronagraphs

4.1 Use-case #1 - Characterization of a known planet

4.1.1 Description

This use-case corresponds to a proposal to observe and study a known planet (e.g. a planet previously imaged in the near-infrared by a ground-based instrument such as the Gemini Planet Imager or VLT-SPHERE). Typically this type of program will include observations in several filters for each instrument (both NIRCam and MIRI) to achieve multi-wavelength characterization of the planet. This use-case includes both the case of a program for a single target, or for several targets, with no impact on templates or pipeline since the science targets are totally independent and observed sequentially.

4.1.2 Template

The recommended approach is to follow the *basic coronagraphic sequence* (target, 10-deg-roll, reference) for each target, instrument, mask and filter. Here the 10-deg roll provides at least a one pixel-dithering for the planet at all separations.

There are several ways the observations can be ordered in APT, with significant impact on overhead and potentially performance. The options can be bound between two most interesting cases i) Minimum time between each target-reference pairs, with every sequence (target, roll, ref) scheduled back-to-back ii) Minimum number of rolls and slews to maximize efficiency with observations grouped by instrument for simplicity (see examples below). It may be possible to use the APT super-template to generate automatically these two types of optimizations (e.g. with a toggle button). These configurations are studied in another technical report [TR3]. Based on this study the recommended configuration is the one that guarantees maximum efficiency. Any other configuration would generate a warning and will require additional technical justification as being a non-standard mode.

Since we do not have sufficient information about wavefront stability at this time, it is possible that this default recommendation will evolve in later cycles (i.e. we may recommend to switch to a less efficient configuration) after actual observatory performance is well understood. A feature in APT to generate these two types of optimization would allow us to update the recommended configuration easily. In any case even if a single configuration is implemented there should be an easy mechanism to update this optimization scheme at a later time.

Additional template need for this use-case: it will be necessary to have the ability to take a full frame image to locate some background sources and perform precise astrometry of the star. For both NIRCam and MIRI, this would most likely use a different filter (broader band) to facilitate the detection of background object, either through the template (with coronagraphic mask in place) or using a standard non-coronagraphic imaging template with full detector read, e.g. in a broadband filter. In any case, it would be preferable to implement the option for this “astrometric full frame image” at the super-template level so that the observations are organized and linked properly, as shown in the mockup implementation figures with the “astrometric calibration” checkbox. The details are discussed in [TR5].

4.1.3 Pipeline

Generate classical PSF subtraction for each orient and combined products in each filter (i.e. all subtracted images properly de-rotated and co-added and astrometrically corrected) in each filter. Pipeline option for self-subtraction between both rolls, useful for NIRCam and MIRI at large angular separations (aka Angular Differential Imaging, ADI). Pipeline option for using additional PSFs from PSF library. Pipeline option for using a small-grid dither pattern if included in the program.

4.1.4 ETC

Standard mode, ETC uses pre-calculated covariance matrix corresponding to the classical PSF subtraction, and/or more sophisticated reduction algorithms (LOCI/KLIP).

4.1.5 Policies

In this use-case the references have been specifically selected to be good calibration stars, so these reference PSFs become public immediately.

4.1.6 Example

One science target, one reference star, and observations in all MIRI coronagraphs and 3 NIRCam filters with 2 masks. See [TR3] for more details on the implementation.

Configuration 1: Best efficiency (minimizing the number of rolls and slew) but still grouped by instrument for simplicity. This is the preferred standard approach for the initial implementation as detailed in [TR3]. In theory it may be possible to have higher efficiency by interleaving observations by instrument to save a few rolls, but this is not not being considered here. This is the preferred standard approach for the initial implementation. Each of the *coronagraphic sequence* (observations for a given target and its associated reference) is expected to be back-to-back ("sequence NON-INT")

target_1, MIRI, 4QPM, F1065, -5deg

target_1, MIRI, 4QPM, F1140, -5deg

target_1, MIRI, 4QPM, F1550, -5deg

target_1, MIRI, 4QPM, F1065, 5deg

target_1, MIRI, 4QPM, F1140, 5deg

target_1, MIRI, 4QPM, F1550, 5deg

PSF1, MIRI, 4QPM, F1065

PSF1, MIRI, 4QPM, F1140

PSF1, MIRI, 4QPM, F1550

Note: in the case of MIRI each science filter involves an independent target acquisition, which requires moving the filter wheel to the ND filter at least for bright targets. Therefore the ordering of the science filter does not impact efficiency for most cases.

target_1, NIRCam, MBLW, F360M, -5deg

target_1, NIRCam, MBLW, F410M, -5deg

target_1, NIRCam, MBLW, F460M, -5deg

target_1, NIRCam, MBLW, F360M, 5 deg

target_1, NIRCam, MBLW, F410M, 5 deg

target_1, NIRCam, MBLW, F460M, 5 deg

PSF1, NIRCam, MBLW, F360M

PSF1, NIRCam, MBLW, F410M

PSF1, NIRCam, MBLW, F460M

Configuration 2: Minimization of time between each target/reference pairs (possibly higher performance, but higher cost / lower efficiency)

target_1, MIRI, 4QPM, F1065, -5deg

target_1, MIRI, 4QPM, F1065, 5deg

PSF1, MIRI, 4QPM, F1065

--

target_1, MIRI, 4QPM, F1140, -5deg

target_1, MIRI, 4QPM, F1140, 5deg

PSF1, MIRI, 4QPM, F1140
--
target_1, MIRI, 4QPM, F1550, -5deg
target_1, MIRI, 4QPM, F1550, 5deg
PSF1, MIRI, 4QPM, F1550
--
target_1, NIRCam, MBLW, F360M, -5deg
target_1, NIRCam, MBLW, F360M, 5 deg
PSF1, NIRCam, MBLW, F360M
--
target_1, NIRCam, MBLW, F410M, -5deg
target_1, NIRCam, MBLW, F410M, 5 deg
PSF1, NIRCam, MBLW, F410M
--
target_1, NIRCam, MBLW, F460M, -5deg
target_1, NIRCam, MBLW, F460M, 5 deg
PSF1, NIRCam, MBLW, F460M

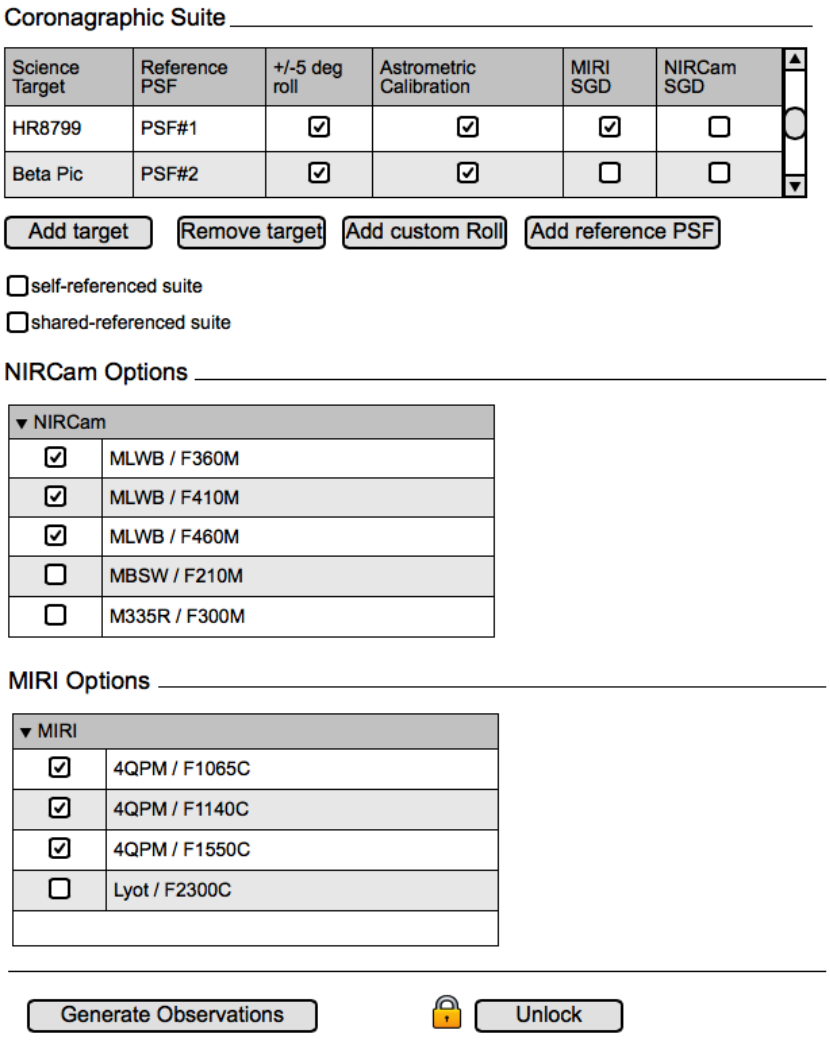

Figure 1 Example of implementation for use-case #1 corresponding to configuration 1: two already known planetary systems are observed with several filters and coronagraphs. In this example, the suite is built on the basic coronagraphic sequence (target, 10deg roll, reference). The example here also shows the use of an optional small grid-dither for MIRI, and both targets use astrometric calibration exposures (not shown in the details of configuration 1). Such an example or program is considered as standard utilization of the coronagraphic mode.

4.2 Use-case #2 - Characterization of a known disk

4.2.1 Description

This use-case corresponds to a proposal to observe and study a known disk at several roll orientations. Here multiple orientations are used to mitigate the disk obscuration by the mask feature (e.g. with a NIRCam bar mask or along the axes of the 4QPM masks). Depending on available orientations as a function of the target's ecliptic latitude, it may be possible to obtain larger rolls than +/- 5 deg but separated in time (i.e. not back to back).

4.2.2 Template

In this use-case, the default *basic coronagraphic sequence* (target, roll, ref) can be generalized to the case of larger rolls (not necessarily scheduled back-to-back) when possible. Indeed the +/-5 deg roll scheduled back-to-back remains interesting in certain cases, but is no longer mandatory if replaced by separate observations at larger roll separations. The rule is simply that the proposal must include at least 2 orientations for each target in each filter. A PSF reference star must be taken at each orientation as part of the standard mode.

4.2.3 Pipeline

Classical or advanced (i.e. using PSF-library) reference subtraction for each orient recombination. Additional products can be considered (e.g. John Krist's iterative roll/recombination). We may consider the possibility at the super template level to indicate whether the target is classified as a "point source" or "extended-source", as we could use this information for different treatment in the pipeline in order to avoid self-subtraction of the target at different roll angles (i.e. Angular Differential Imaging mode) for an extended source.

4.2.4 ETC

Must be able to handle extended sources, should be able to use the same tools as for imaging modes.

4.2.5 Policies

In this use-case the references have been specifically selected to be good calibration stars, so these reference PSFs become public immediately. If the +/- 5 deg roll is not used but replaced by at least one other orient at a later epoch, this is considered standard and does not require additional justification. If the user is selecting both the +/-5 deg and larger rolls at the same time there should be a warning to make sure this was not by mistake.

4.2.6 Example

Configuration1: *basic coronagraphic sequence* with a +/- 5 deg roll, followed by a series of observations at a later date to obtain a larger roll (if possible for that target). Zero degree is the nominal roll at the first epoch and 45 deg the nominal orientation at the second epoch; Therefore the for orientations taking advantage of the +/- 5 deg roll (10 deg total) are: -5deg, +5deg, 40deg, 50deg. Each two coronagraphic sequences are non-interruptible. The recommended implementation within each sequence is the most efficient (see [TR3]). This is considered as a standard use of JWST coronagraph and does not require additional justification.

--

target_1, MIRI, 4QPM, F1065, -5deg

target_1, MIRI, 4QPM, F1550, -5deg

target_1, MIRI, 4QPM, F1550, +5deg

target_1, MIRI, 4QPM, F1065, +5deg

PSF1, MIRI, 4QPM, F1065

PSF1, MIRI, 4QPM, F1550

--

target_1, MIRI, 4QPM, F1065, 40deg

target_1, MIRI, 4QPM, F1550, 40deg

target_1, MIRI, 4QPM, F1065, 50deg

target_1, MIRI, 4QPM, F1550, 50deg

PSF1, MIRI, 4QPM, F1065

PSF1, MIRI, 4QPM, F1550

--

Configuration2: The +/-5 deg roll is avoided, but replaced by a larger roll at a later epoch. Each observation of the target has its own back-to-back observation of the reference star. This is considered as a standard use of JWST coronagraphs and does not require additional justification.

target_1, MIRI, 4QPM, F1065, 0deg

target_1, MIRI, 4QPM, F1550, 0deg

PSF1, MIRI, 4QPM, F1065

PSF1, MIRI, 4QPM, F1550

--

target_1, MIRI, 4QPM, F1065, 45deg

target_1, MIRI, 4QPM, F1550, 45deg

PSF1, MIRI, 4QPM, F1065

PSF1, MIRI, 4QPM, F1550

Note: As with use-case #1 there could be various ways to organize the observations, the default being the most efficient (while minimizing the time between target and reference). Other configurations not defined in this document could be implemented in APT by leaving the super-template and using the manual mode, but would require additional technical justification.

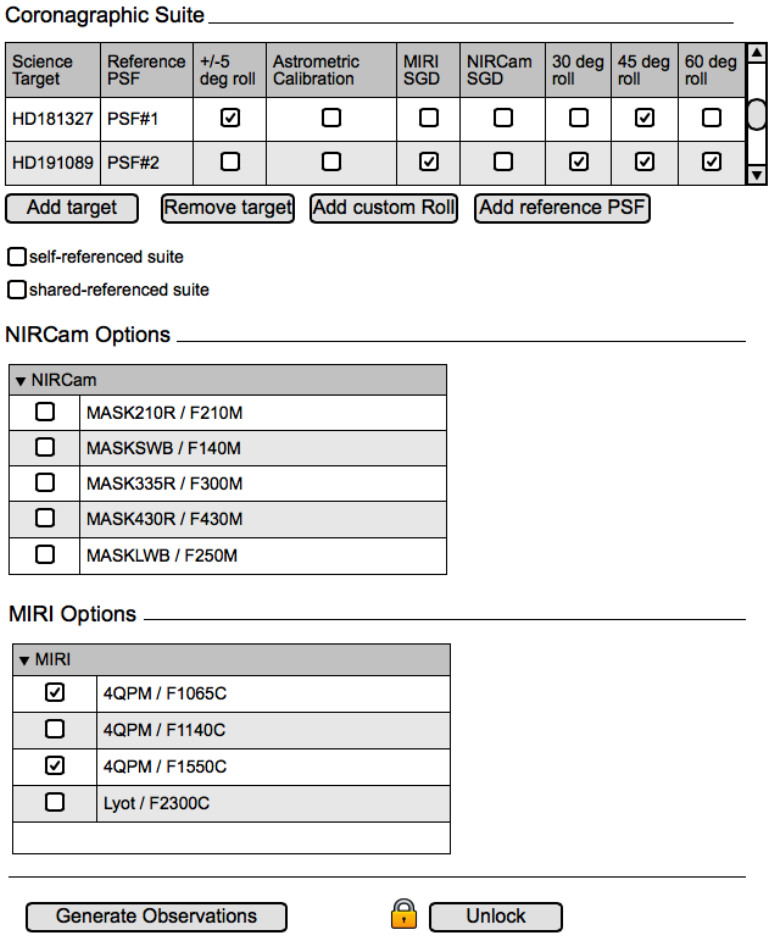

Figure 2 Example of implementation for use-case #2: In this example two known debris disks are observed with NIRCam and MIRI. The first target corresponds to the implementation described in configuration #1 with both the +/- 5 deg roll and a second-epoch 45-degree roll. The second target departs from this configuration and is similar to what is described in configuration 2, where the +/- 5 deg roll is omitted for efficiency and replaced by several roll angles at later epochs. Each science target has its own reference PSF, and the second target also takes advantage optional dithers in this example. Such a program example is considered a standard use of the coronagraphic mode.

4.3 Use-case #3 - Self-referenced survey of several targets

4.3.1 Description

This use-case corresponds to a survey to search for new disks or planets, which are unknown at the time of the proposal. From a selected list of targets (e.g. 20 stars), the observer expects to detect a number of new objects, but does not know around which target(s) they will be found. The targets without interesting structures become PSF reference stars, but are not identified as such until after the data are analyzed. This type of proposal is important scientifically and likely to be common; it is considered a standard use of the coronagraphic modes. Since these types of programs are designed to search for new objects, it is anticipated that they will operate in a single filter or at least in a small number of filters to minimize the amount of time spent on potentially unprofitable

targets. Identified new objects of interest can then be followed up with another proposal (following use-case #1).

With this type of survey each science target can also potentially serve as a reference PSF for the other targets in the proposal. In an iterative process targets with detected disks or point sources are successively removed from the reference PSF stack. Once the entire survey has been analyzed, the observer can determine which stars are good reference PSFs (i.e. the ones with non-detections), and these can be added to the PSF library (see [TR10] for details).

Although this type of proposal generates several reference PSFs (e.g. a program with 20 targets might lead to 5 new discovered objects, and 15 reference PSFs), some of the targets may be spread over the sky and not be schedulable back-to-back, while other groups of targets might be sufficiently close to be scheduled together.

We use the term "*self-referenced suite*" to denote a group of such targets that can be scheduled together as a coronagraphic suite, where each target is a potential good reference for each other within that group. A self-reference suite therefore does not necessarily require additional reference PSFs (or to be conservative one or a small number of references). *Self-referenced suites* are expected to be scheduled back-to-back (sequence non-int) as a best effort, since the scheduling complexities might not allow a secure prediction of whether this is feasible at this stage of APT input. For stars that cannot be scheduled back to back with other stars of the survey, the default mode reverts to the *basic coronagraphic sequence* with a dedicated reference PSF for best performance (see use-case#1). A complete survey might for example consist of self-referenced suites for groups of targets that can be scheduled together, with some isolated targets that require their own reference PSF. The manual mode of APT allows the user to configure the proposal in non-standard ways (e.g. with fewer or more reference stars), but reducing the number of reference targets generates a warning that requires additional technical justification.

With the implementation of PSF libraries and advanced subtraction algorithms (LOCI, KLIP/PCA), the need for additional reference PSFs may be mitigated for these survey-type programs, especially for large surveys. Experience reprocessing HST archival surveys (Archival Legacy Investigation of Circumstellar Environments, ALICE) has demonstrated that the performance with a large number of references from a survey outperforms a PSF subtraction with a single back-to-back reference PSF by over an order of magnitude in contrast. Therefore it may be more effective in practice to add science targets (if they exist) rather than add reference PSFs, increasing both potential discoveries and the size of the reference PSF library. However the answer to this question will likely not be known until actual data are obtained and analyzed, so it is important to design the systems with sufficient flexibility.

4.3.2 Template

Support for this type of proposal in APT is necessary since a fully manual implementation would be particularly painstaking given the number of targets, and prone to errors or poorly-designed observing strategies. A coronagraphic suite can be simply indicated in the super-template with a check box for each coronagraphic suite to indicate

it is “self-referenced”. This information is necessary at the super-template level since it needs to be propagated to other components (e.g. policies, pipeline) as detailed below.

Checking the “self-reference” box means the science targets in the suite can be used as reference PSFs for each other, and therefore APT does not need to issue an error requiring justification if it detects missing reference PSFs for the coronagraphic suite. Of course it should be possible to add reference PSFs for some/all of the targets in addition of being self-referenced, and this would be then taken into account by the pipeline.

The “self-reference” check box should trigger a warning about the need to make sure that the stars within the coronagraphic suite can be scheduled together. Ideally APT would be able to provide some information or additional tools for that purpose. Initial implementation will consider an arbitrary criterion to represent schedulability, e.g. being within 5 degree of each other.

One telescope roll around normal position is recommended for each target (with the +/-5 deg being the default) in order to provide at least a pixel-dithering effect, and Angular Differential Imaging (ADI) capabilities at larger separations (aka roll deconvolution, i.e. when subtracting a target from itself at different orientations). Similarly to use-case #2, the observer may want to replace the +/-5 deg roll by a larger roll at a later date (if achievable for that target), which may be more interesting in the case of a survey searching for disks. In that case APT would organize the observations into two suites at different orientations (see example below).

4.3.3 Pipeline

The pipeline uses the self-referencing flag and identifies what data is available (i.e. determines the set of potential reference PSFs for each target). Then it applies a classical reference subtraction if a "dedicated reference PSF exists", otherwise uses e.g. a median of all possible reference PSFs, and/or more advanced LOCI/KLIP reduction combining the reference set. A basic reduction following these simple rules can be provided automatically, but the full analysis of such programs cannot be done automatically and will require using the pipeline software package provided to the users (see [TR7]) .

4.3.4 ETC

This survey mode is designed with the standard ETC paradigm. The ETC can be bound between a conservative estimate using classical reference subtraction, and an estimate using a reference library where the reference stars are provided by the survey itself and/or complemented by existing reference PSFs.

4.3.5 Policies

The “self-referencing” checkbox for a coronagraphic suite allow the user to skip explicit reference PSFs for that suite. Every target is treated as a science target and therefore has the standard JWST proprietary period. Any additional reference PSFs that were added to the survey targets becomes public immediately (i.e. these are selected as “good” reference PSFs). At the end of the program, the observer is required to provide information about which targets have been identified as good references (i.e. with solid non-detections), so that these PSFs can be added to the reference PSF library database in

a timely way and used by other programs (see [TR10] for details). This information can for example be required with the grant's final report, and can also be provided by any user if they identify bad references. In order to preserve some flexibility the manual mode of APT allows configuring the proposal differently (e.g. with fewer reference PSFs) but this would trigger an error requiring additional technical justification.

4.3.6 Examples

Below is one possible implementation of such a program, focusing on some filter to be determined by the science case and a similarly chosen coronagraphic mask. In this example there are 7 targets total, with two self-reference suites plus one additional isolated target that requires its own reference.

self-reference suite1

target_1, NIRCam, M430R, F430M, -5deg

target_1, NIRCam, M430R, F430M, 5deg

target_2, NIRCam, M430R, F430M, -5deg

target_2, NIRCam, M430R, F430M 5deg

target_3, NIRCam, M430R, F430M, -5deg

target_3, NIRCam, M430R, F430M 5deg

self-reference suite2

target_4, NIRCam, M430R, F430M, -5deg

target_4, NIRCam, M430R, F430M, 5deg

target_5, NIRCam, M430R, F430M, -5deg

target_5, NIRCam, M430R, F430M, 5deg

target_6, NIRCam, M430R, F430M, -5deg

target_6, NIRCam, M430R, F430M, 5deg

isolated target

target_7, NIRCam, M430R, F430M, -5deg

target_7, NIRCam, M430R, F430M, 5deg

PSF1, NIRCam, M430R, F430M

Other option with larger rolls, replacing the +/-5 deg roll, e.g. for a disk survey (similar to use-case #2)

self-reference suite1

target_1, NIRCam, M430R, F430M

target_2, NIRCam, M430R, F430M

target_3, NIRCam, M430R, F430M

self-reference suite2

target_1, NIRCam, M430R, F430M, 30deg

target_2, NIRCam, M430R, F430M, 30deg

target_3, NIRCam, M430R, F430M, 30deg

self-reference suite3
target_4, NIRCam, M430R, F430M
target_5, NIRCam, M430R, F430M
target_6, NIRCam, M430R, F430M
self-reference suite4
target_4, NIRCam, M430R, F430M, 30deg
target_5, NIRCam, M430R, F430M, 30deg
target_6, NIRCam, M430R, F430M, 30deg
isolated target
target_7, NIRCam, M430R, F430M, -5deg
target_7, NIRCam, M430R, F430M, 5deg
PSF1, NIRCam, M430R, F430M

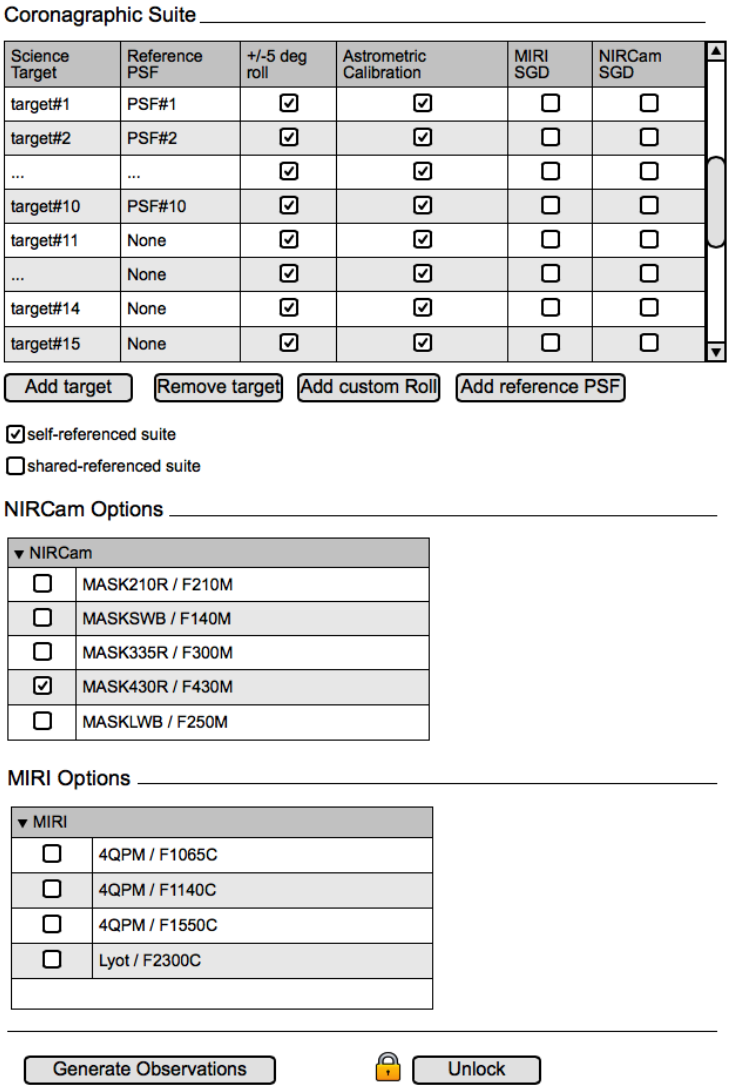

Figure 3 Example of implementation for use-case #3: this example is slightly different from what is described in the text and consists of a self-reference survey of 15 targets each using the standard +/- 5 deg roll, and astrometric calibration, but only 10 reference PSFs (Note the second column values is "None" for target 11 to 15. The self-referenced-suite option is checked, and a sufficient number of reference PSFs is used. This is considered as standard use of the coronagraphic mode.

4.4 Use-case #4 - Shared reference surveys

4.4.1 Description

This use-case also corresponds to a survey, but differs in the implementation. In this use-case, the science targets are not potential good references for each other. This happens when structures are expected to be detected around each or most of the targets (e.g. a proposal to observe a number of known debris disks). Since the targets cannot serve as reference for each other, the proposal must include adequate reference PSF for each target. In the event where the targets also happen to be grouped in the same region of the

sky (e.g. a survey of a few T-Tauri stars), it is conceivable that targets "share" reference PSFs with groups of targets and their reference being scheduled back-to-back.

4.4.2 Template

This use-case also takes advantage of the coronagraphic suite as in Use-case #3 where the suite's targets can be scheduled together (back-to-back). Here the coronagraphic suite includes at least one reference PSF, which is shared by the suite's targets.

4.4.3 Pipeline

The pipeline implementation is identical to use-case #3, except that in this case the classical PSF subtraction may be the only option (single reference PSF, and not necessary other available PSFs from the library.

4.4.4 ETC

same as for use-case #3

4.4.5 Policies

With the concept of coronagraphic suite for targets that can be scheduled together, APT can detect the "shared reference" situation if there is a single reference PSF for that suite. Under this paradigm, APT would be able to recognize the situation as acceptable without issuing an exception. An implementation alternative would be to offer a check box similar to the "self-reference suite" selection, but for a "shared reference suite".

4.4.6 Examples

target_1, NIRCam, M430R, F430M, -5deg
target_1, NIRCam, M430R, F430M, 5deg
target_2, NIRCam, M430R, F430M, -5deg
target_2, NIRCam, M430R, F430M, 5deg
target_3, NIRCam, M430R, F430M, -5deg
target_3, NIRCam, M430R, F430M, 5deg
PSF1, NIRCam, M430R, F430M
(...)

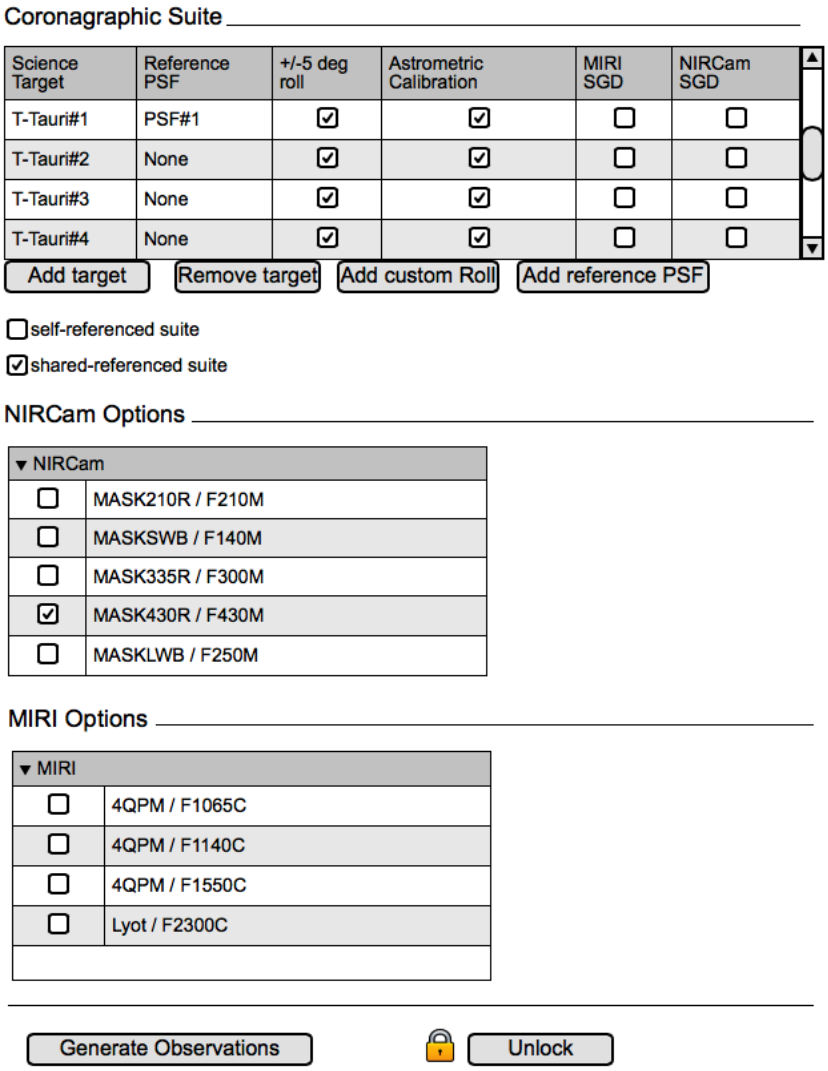

Figure 4 Example of implementation for use-case #4: Example of observations of 4 targets at moderate contrast, presumably in the same region of the sky and schedulable together. In this case, a single reference PSF is selected, and the option "shared-reference suite" is activated. This is considered a standard use of the coronagraphic mode and the user would get a warning to make sure this is justified as part of the *standard* technical justification. Here the illustration also includes the optional astrometric calibration.

4.5 Use-case #5 - Easy targets

4.5.1 Description

This use-case corresponds to low hanging fruits for the JWST coronagraphs, i.e. where the science value of the proposal resides in the observation of a target at JWST wavelengths, but where the target is very easy to reach with the coronagraphs in terms of contrast and inner working angle. In this situation the observer may request arguably a more aggressive observing strategy. A couple of examples are given below:

- A reference PSF may not be needed for the characterization of a point source at large angular separation where the ADI subtraction is effective. The user can use the manual mode and delete the reference PSF. This would require an additional technical justification which is straightforward in this case (ADI mode).

- skipping the +/- 5deg roll might be acceptable in some situation (e.g. an astrometric confirmation, but without the need for very accurate photometry).

4.5.2 Template

This type of program does not require additional feature. From the super-template, the user can skip reference PSFs or rolls for any targets, which will require additional technical justification.

4.5.3 Pipeline

The pipeline follows the same process as for the other use-cases and determines the course of action depending on what data is available. For example if no reference PSF is available but adequate PSFs can be found in the library it performs the subtraction with PSFs from the library.

4.5.4 ETC

This use-case does not have any particular additional needs for ETC.

4.5.5 Policies

This use-case does not have any particular additional needs for policies. Reference PSFs become public immediately if included in the program. Any non-standard use (i.e. missing references, or missing rolls) require additional technical justification.

4.5.6 Examples

target_1, NIRCam, M430R, F430M

target_1, NIRCam, M430R, F430M, 10deg

4.6 Use-case #6 - Observation at the limit of capabilities

4.6.1 Description

This corresponds to the case where the user is pushing the limits of the instrument and trying to observe a planet or disk at the limits of JWST's coronagraphic capabilities. This could involve the use of small-grid dithers, or possibly additional reference PSFs and/or rolls for the science targets. This includes also the possibility to add rolls on the reference star, a technique used to increase robustness to unknown structure around the star (e.g. if the chosen reference star turns out to be a binary star, or has a bright disk). Since JWST opens up a new parameter space in terms of wavelength coverage, it is likely that most possible reference stars will have little *a priori* information about what they look like at JWST wavelengths.

4.6.2 Template

At the super-template level the starting point for such a proposal is identical to use-case #1 with the *basic coronagraphic sequence* (target, roll, reference) and where the user can add optional observations (e.g. small grid dithers, additional rolls, roll on the reference star to provide robustness against bad reference star, small grid dither on target, more than one reference PSF for a given target). Since any of these features add to the total observing time, it is expected that the user will work to determine the optimal configuration, and there is no need for APT to issue an exception.

4.6.3 Pipeline

For this type of 'expert-level' proposal, it is expected the user will use their own data reduction pipeline, The automated pipeline will process these data in a similar fashion to previously described use-cases. The pipeline can detect the presence of small-grid dithers and propose an automatic reduction with all references available.

4.6.4 ETC

ETC support for small-grid dithers will include a dedicated covariance matrix, otherwise there is no additional support to be provided.

4.6.5 Policies

Since this use case adds complexity to the program with more observations and therefore render the program more expensive, there is no need for additional policies.

4.7 Use-case #7 - Faint target/extragalactic observation

4.7.1 Description

This would correspond to fainter targets (e.g. AGN hosts imaging). This use-case does not require anything different and is covered by use-case #1 and use-case #2, depending on the roll situation.

4.7.2 Template

This use case does not require anything different at the super template level, only at the template level there is a need for a different target acquisition (faint target acquisition mode).

4.7.3 Pipeline

Identical as previous use-cases.

4.7.4 ETC

Identical to previous use-cases.

4.7.5 Policies

Identical to previous use-cases.

4.8 Use-case #8 - Unconventional observations

4.8.1 Description

This generic use-case covers unconventional types of proposal that may be proposed. Although there is no plan to provide support, the goal is to simply list them and check that the chosen implementation is robust to these types of proposals.

e.g. characterization of two planets system with orientation such that each targets can be used as reference for each other.

e.g. binary star system putting the two stars both behind the NIRCam wedge occulter (may or may not be possible depending on ecliptic latitude)

e.g. some situation where the user just want to avoid saturation and not require roll or references

4.8.2 Template

This is covered by the same concept as above, likely making use of the fully manual mode of APT, and providing additional technical justification.

4.8.3 Pipeline

no support for this use-case. Pipeline must be robust to data presented where reference PSFs or rolls do not exist.

4.8.4 ETC

no support for this use-case.

4.8.5 Policies

manual/custom proposals require additional technical justification.

5 Summary and future work

This technical report presented the range of possible science use-cases for the JWST coronagraphs. The purpose is to guide the development of APT super-templates, and of the pipeline to specify how each of the data sets will be processed. At the time of this report it was determined that the super-template in APT will not be available until Cycle 2, therefore additional work will be necessary to evaluate whether and how these science use-case can be implemented with the current version of APT.