



# 4023 - Complete NIRSpec coverage of Europa's surface: CO<sub>2</sub>, salt hydrates, and the potential for unexpected discovery

Cycle: 2, Proposal Category: GO

## INVESTIGATORS

| <i>Name</i>                     | <i>Institution</i>                 |
|---------------------------------|------------------------------------|
| <b>Dr. Samantha Trumbo (PI)</b> | <b>Cornell University</b>          |
| Dr. Michael E Brown (CoI)       | California Institute of Technology |
| M. Ryleigh Davis (CoI)          | California Institute of Technology |

## OBSERVATIONS

| <i>Folder</i>                                      | <i>Observation</i> | <i>Label</i>                             | <i>Observing Template</i> | <i>Science Target</i> |
|--|--------------------|--|---------------------------|-----------------------|
| NIRSpec observations of all three phases of Europa |                    |  |                           |                       |
|  | 1                  | Europa anti-Jovian NIR spec IFU high res | NIRSpec IFU Spectroscopy  | (1) EUROPA            |
|  | 2                  | Europa trailing NIRspec IFU high res     | NIRSpec IFU Spectroscopy  | (1) EUROPA            |
|  | 3                  | Europa sub-Jovian NIR spec IFU high res  | NIRSpec IFU Spectroscopy  | (1) EUROPA            |

## ABSTRACT

JWST NIRSpec presents the singular opportunity to observe the surface of Europa across the entirety of its largely unexplored 2.5–5 micron range at a combination of spectral resolution, sensitivity, and spatial resolution inaccessible to any existing or planned telescope or spacecraft mission. Such observations would address decades-old questions concerning the origin and nature of its surface CO<sub>2</sub> and its widespread “hydrate” material interpreted to contain ocean-derived salts. Preliminary results from the single Cycle 1 GTO NIRSpec observation of Europa are remarkable, and already reveal new surface absorption features and enticing clues to the possible oceanic origin and perplexing physical state of the CO<sub>2</sub>. However, it does not provide the complete spatial coverage of Europa’s large-scale resurfaced terrain needed to decisively determine whether the CO<sub>2</sub> truly

originates from the ocean, nor does it provide any coverage of the compositionally distinct trailing hemisphere, which features an unidentified and unmapped absorption feature at 3.78 microns potentially diagnostic of the composition of inferred oceanic salt hydrates. We propose a straightforward NIRSpec IFU mapping campaign to complete spatially resolved coverage of the surface across the 2.5–5 micron wavelengths in order to (i) determine whether Europa's CO<sub>2</sub> truly originates from ocean material and constrain its physical state, (ii) test the hypothesis that Europa's 3.78-m band results from Na/Mg-sulfate salt, and (iii) produce complete spatially resolved maps of Europa's heterogeneous surface in this poorly explored wavelength range.

## **OBSERVING DESCRIPTION**

We propose to observe Europa using NIRSpec in IFU mode and the G235H/F170LP and G395H/F290LP grating/filter combinations across three rotational phases of the satellite not covered by Cycle 1 GTO program #1250. These proposed data will provide complete spatially resolved coverage of the surface in the largely unexplored 2.5-5 micron wavelength range at a combination of spectral resolution, spatial resolution, and sensitivity exclusively accessible with JWST.

These observations will provide high S/N, spatially resolved measurements of the 2.7-micron and 4.26-micron CO<sub>2</sub> bands and the unidentified 3.78-micron band on the trailing hemisphere, allowing us to map the strengths and positions of these features at the scale of Europa's large-scale resurfaced terrain and determine whether they are consistent with endogenic or exogenic origins.

Our G235H S/N requirements are set by the known strengths of the CO<sub>2</sub> band in the existing Cycle 1 NIRSpec observations and the desire to replicate an equivalent quality of measurement and spatial mapping of this absorption, in combination with the possibility of searching for the additional 2.78-micron band of CO<sub>2</sub> in ice-poor regions. Our G395H S/N requirements are set by the known strength of the 3.78-micron band from ground-based disk-integrated spectra. As the feature is weak (<2%) and likely associated with Europa's darkest terrain, our integration times in G395H are longer than those used in the GTO program. Scaling from the existing data and performing ETC calculations both agree that our proposed exposures should provide the necessary S/N without risk of saturation.

Critically, we will use a 4-point dither pattern for all exposures, as the 2-dither approach of the Cycle 1 GTO program failed to minimize the impact of bad pixels, resulting in an unfortunately large number of pixels that were not usable, even after dither combination. No target acquisitions are required.

To maximize the spatial coverage and resolution, we constrain our observations of each rotational phase to a 20-degree window—10-30 degrees W

## JWST Proposal 4023 (Created: Wednesday, April 10, 2024 at 12:00:39 PM Eastern Standard Time) - Overview

for the sub-Jovian hemisphere, 190-210 degrees W for the anti-Jovian hemisphere, and 280-300 degrees W for the trailing hemisphere. To maximize spatial resolution, we also request a near-maximum target angular diameter of  $>0.9$  arcseconds. By off-setting these windows so start 10 degrees west of the perfectly sub-Jovian, anti-Jovian, and trailing points, we simultaneously minimize gaps in high-resolution spatial coverage and ensure sufficiently long observing windows at greater than 37-arcsecond separations from the limb of Jupiter to minimize the potential impact of scattered light. We use publicly available NIRSPec G235H and G395H observations of Io in eclipse at a limb-limb separation of  $\sim 8$  arcseconds (from ERS program #1373) in order to estimate that the effects of scattered light in terms of both noise and signal contributions will be small ( $<1\%$ ), and thus not a concern for our observations. The default separations of Europa from its neighboring satellites should be fine for our purposes. In terms of scheduling, the requested three phases of Europa need not be obtained within a single Jupiter orbit of Europa itself. There are several observing windows for each phase that are within JWST's optimal observing constraints.

Proposal 4023 - Targets - Complete NIRSpec coverage of Europa's surface: CO2, salt hydrates, and the potential for unexpected disc...

| Solar System Targets          | #   | Name   | Level 1     | Level 2    | Level 3 |
|-------------------------------|-----|--------|-------------|------------|---------|
|                               | (1) | EUROPA | STD=JUPITER | STD=EUROPA |         |
| <i>Comments: Extended=YES</i> |     |        |             |            |         |

Proposal 4023 - Observation 1 - Complete NIRSpec coverage of Europa's surface: CO2, salt hydrates, and the potential for unexpecte...

Wed Apr 10 17:00:39 GMT 2024

| <b>Observation</b>            | Proposal 4023, Observation 1: Europa anti-Jovian NIRspec IFU high res<br><b>Diagnostic Status: Warning</b><br>Observing Template: NIRSpec IFU Spectroscopy  |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|-------------------------------|---|----------------|-----------------|----------------|------------------|---------|--------|---------|---------------|--------------------|---------------------|------------------|---|----------------|-----------------|----------------|------------------|---------|--------|-------------|---------------|--------------------|-------------------------------|------------------|---|--------------|----------|---|---|-------|------|------|---|----|---------|--|---|--------------|----------|---|---|-------|------|------|---|----|----------|--|
|                               | (Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.<br>(Europa anti-Jovian NIRspec IFU high res (Obs 1)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.  |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Diagnostics</b>            |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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|                               | #   | Name           | Level 1         | Level 2        | Level 3          |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| (1)                           | EUROPA  | STD=JUPITER    | STD=EUROPA      |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <i>Comments: Extended=YES</i> |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Template</b>               | TA Method   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               | NONE  |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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| 1                             | CYCLING   | SMALL          | 1               | 4              |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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|                               | 1   | G235H/F170LP   | NRSRAPID        | 2              | 5                | false   | true   | NONE    | 4             | 20                 | 644.206             |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| 2                             | G395H/F290LP  | NRSRAPID       | 5               | 5              | false            | true    | NONE   | 4       | 20            | 1288.412           |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Special Requirements</b>   | DEFAULT WINDOW: NOT OCCULTATION OF EUROPA BY JUPITER FROM JWST<br>DEFAULT WINDOW: SEPARATION OF EUROPA IO FROM JWST GREATER THAN 10"<br>DEFAULT WINDOW: SEPARATION OF EUROPA GANYMEDE FROM JWST GREATER THAN 10"<br>DEFAULT WINDOW: SEPARATION OF EUROPA CALLISTO FROM JWST GREATER THAN 10"<br>DEFAULT WINDOW: ANGULAR RATE EUROPA FROM JWST LESS THAN 0.075<br>CENTRAL MERIDIAN LONGITUDE OF EUROPA FROM JWST BETWEEN 150 170<br>APPARENT DIAMETER EUROPA GREATER THAN 0.9<br>SEPARATION OF EUROPA JUPITER FROM JWST GREATER THAN 27"   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |   |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |

Proposal 4023 - Observation 2 - Complete NIRSpec coverage of Europa's surface: CO2, salt hydrates, and the potential for unexpecte...

| <b>Observation</b>            | Proposal 4023, Observation 2: Europa trailing NIRspec IFU high res <span style="float: right;">Wed Apr 10 17:00:39 GMT 2024</span><br><b>Diagnostic Status: Warning</b><br>Observing Template: NIRSpec IFU Spectroscopy   |  |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|-------------------------------|---|--|-----------------|----------------|------------------|---------|--------|---------|---------------|--------------------|---------------------|------------------|----------------|-----------------|------------|------------------|------------------|--------|---------|---------------|--------------------|---------------------|-------------------------------|---|--------------|----------|---|---|-------|------|------|---|----|---------|--|---|--------------|----------|---|---|-------|------|------|---|----|----------|--|
|                               | <b>Diagnostics</b>  | (Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.<br>(Europa trailing NIRspec IFU high res (Obs 2)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.<br>(Visit 2:1) Informational (Form): Visit schedulable, but most scheduling windows are when JWST is pointed in direction of greatest micrometeoroid impact risk. This is likely due to scheduling special requirements. |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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|                               | #   | Name   | Level 1         | Level 2        | Level 3          |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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| <i>Comments: Extended=YES</i> |   |  |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Template</b>               | <b>TA Method</b><br>NONE  |  |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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| #                             |   | Dither Type  | Size            | Starting Point | Number of Points | Points  |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| 1                             | CYCLING   | SMALL  | 1               | 4              |                  |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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|                               | #   | Grating/Filter   | Readout Pattern | Groups/Int     | Integrations/Exp | Leakcal | Dither | Autocal | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               | 1   | G235H/F170LP   | NRSRAPID        | 2              | 5                | false   | true   | NONE    | 4             | 20                 | 644.206             |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| 2                             | G395H/F290LP  | NRSRAPID   | 5               | 5              | false            | true    | NONE   | 4       | 20            | 1288.412           |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Special Requirements</b>   | Between Dates 08-SEP-2024:00:00:00 and 28-OCT-2024:00:00:00<br>Between Dates 12-OCT-2025:00:00:00 and 01-DEC-2025:00:00:00<br>Between Dates 14-NOV-2026:00:00:00 and 02-JAN-2027:00:00:00<br>Between Dates 14-DEC-2027:00:00:00 and 01-FEB-2028:00:00:00<br><br>SEPARATION OF EUROPA JUPITER FROM JWST GREATER THAN 27"<br>CENTRAL MERIDIAN LONGITUDE OF EUROPA FROM JWST BETWEEN 250 270<br>APPARENT DIAMETER EUROPA GREATER THAN 0.9<br>DEFAULT WINDOW: NOT OCCULTATION OF EUROPA BY JUPITER FROM JWST<br>DEFAULT WINDOW: SEPARATION OF EUROPA IO FROM JWST GREATER THAN 10"<br>DEFAULT WINDOW: SEPARATION OF EUROPA GANYMEDE FROM JWST GREATER THAN 10"<br>DEFAULT WINDOW: SEPARATION OF EUROPA CALLISTO FROM JWST GREATER THAN 10"<br>DEFAULT WINDOW: ANGULAR RATE EUROPA FROM JWST LESS THAN 0.075 |  |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |            |                  |                  |        |         |               |                    |                     |                               |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |

Proposal 4023 - Observation 3 - Complete NIRSpec coverage of Europa's surface: CO2, salt hydrates, and the potential for unexpecte...

| <b>Observation</b>            | Proposal 4023, Observation 3: Europa sub-Jovian NIRspec IFU high res <span style="float: right;">Wed Apr 10 17:00:39 GMT 2024</span><br><b>Diagnostic Status: Warning</b><br>Observing Template: NIRSpec IFU Spectroscopy   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|-------------------------------|---|----------------|-----------------|----------------|------------------|---------|--------|---------|---------------|--------------------|---------------------|------------------|----------------|-----------------|----------------|------------------|---------|--------|-------------|---------------|--------------------|-------------------------------|------------------|---|--------------|----------|---|---|-------|------|------|---|----|---------|--|---|--------------|----------|---|---|-------|------|------|---|----|----------|--|
|                               | (Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.<br>(Europa sub-Jovian NIRspec IFU high res (Obs 3)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.<br>(Visit 3:1) Informational (Form): Visit schedulable, but most scheduling windows are when JWST is pointed in direction of greatest micrometeoroid impact risk. This is likely due to scheduling special requirements.  |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Diagnosics</b>             |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Solar System Targets</b>   | <table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Level 1</th> <th>Level 2</th> <th>Level 3</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>EUROPA</td> <td>STD=JUPITER</td> <td>STD=EUROPA</td> <td></td> </tr> <tr> <td colspan="5"><i>Comments: Extended=YES</i></td> </tr> </tbody> </table>   |                |                 |                |                  |         |        |         |               |                    |                     | #                | Name           | Level 1         | Level 2        | Level 3          | (1)     | EUROPA | STD=JUPITER | STD=EUROPA    |                    | <i>Comments: Extended=YES</i> |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               | #   | Name           | Level 1         | Level 2        | Level 3          |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| (1)                           | EUROPA  | STD=JUPITER    | STD=EUROPA      |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <i>Comments: Extended=YES</i> |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Template</b>               | <b>TA Method</b><br>NONE  |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Dithers</b>                | <table border="1"> <thead> <tr> <th>#</th> <th>Dither Type</th> <th>Size</th> <th>Starting Point</th> <th>Number of Points</th> <th>Points</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>CYCLING</td> <td>SMALL</td> <td>1</td> <td>4</td> <td></td> </tr> </tbody> </table>  |                |                 |                |                  |         |        |         |               |                    |                     | #                | Dither Type    | Size            | Starting Point | Number of Points | Points  | 1      | CYCLING     | SMALL         | 1                  | 4                             |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               | #   | Dither Type    | Size            | Starting Point | Number of Points | Points  |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| 1                             | CYCLING   | SMALL          | 1               | 4              |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| <b>Spectral Elements</b>      | <table border="1"> <thead> <tr> <th>#</th> <th>Grating/Filter</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp</th> <th>Leakcal</th> <th>Dither</th> <th>Autocal</th> <th>Total Dithers</th> <th>Total Integrations</th> <th>Total Exposure Time</th> <th>ETC Wkbk.Calc ID</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>G235H/F170LP</td> <td>NRSRAPID</td> <td>2</td> <td>5</td> <td>false</td> <td>true</td> <td>NONE</td> <td>4</td> <td>20</td> <td>644.206</td> <td></td> </tr> <tr> <td>2</td> <td>G395H/F290LP</td> <td>NRSRAPID</td> <td>5</td> <td>5</td> <td>false</td> <td>true</td> <td>NONE</td> <td>4</td> <td>20</td> <td>1288.412</td> <td></td> </tr> </tbody> </table>   |                |                 |                |                  |         |        |         |               |                    |                     | #                | Grating/Filter | Readout Pattern | Groups/Int     | Integrations/Exp | Leakcal | Dither | Autocal     | Total Dithers | Total Integrations | Total Exposure Time           | ETC Wkbk.Calc ID | 1 | G235H/F170LP | NRSRAPID | 2 | 5 | false | true | NONE | 4 | 20 | 644.206 |  | 2 | G395H/F290LP | NRSRAPID | 5 | 5 | false | true | NONE | 4 | 20 | 1288.412 |  |
|                               | #   | Grating/Filter | Readout Pattern | Groups/Int     | Integrations/Exp | Leakcal | Dither | Autocal | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               | 1   | G235H/F170LP   | NRSRAPID        | 2              | 5                | false   | true   | NONE    | 4             | 20                 | 644.206             |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
| 2                             | G395H/F290LP  | NRSRAPID       | 5               | 5              | false            | true    | NONE   | 4       | 20            | 1288.412           |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |
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|                               |   |                |                 |                |                  |         |        |         |               |                    |                     |                  |                |                 |                |                  |         |        |             |               |                    |                               |                  |   |              |          |   |   |       |      |      |   |    |         |  |   |              |          |   |   |       |      |      |   |    |          |  |