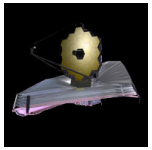

# 2555 - How do ionizing photons escape the Sunburst Arc?

Cycle: 1, Proposal Category: GO

**INVESTIGATORS**

| *Name* | *Institution* |
|---|---|
| **Dr. T. Emil Rivera-Thorsen (PI) (ESA Member)** | **Stockholm University** |
| Dr. Haakon Dahle (CoI) (ESA Member) | University of Oslo |
| Dr. Jane R. Rigby (CoI) (US Admin CoI) | NASA Goddard Space Flight Center |
| Prof. John Chisholm (CoI) | University of Texas at Austin |
| Dr. Matthew Bayliss (CoI) | University of Cincinnati Main Campus |
| Prof. Michael D. Gladders (CoI) | University of Chicago |
| Prof. Matthew James Hayes (CoI) (ESA Member) | Stockholm University |
| Karin Kjellgren (CoI) (ESA Member) | Stockholm University |
| Dr. Guillaume Mahler (CoI) (ESA Member) | Durham Univ. |
| Dr. Michael Florian (CoI) | University of Arizona |
| Soniya Sharma (CoI) | NASA Goddard Space Flight Center |
| Dr. Ramesh Mainali (CoI) | NASA Goddard Space Flight Center |
| Dr. Keunho J. Kim (CoI) | University of Cincinnati Main Campus |
| Dr. Gourav Khullar (CoI) | University of Pittsburgh |
| Prof. Keren Sharon (CoI) | University of Michigan |
| Juan David Remolina Gonzalez (CoI) | University of Michigan |

**OBSERVATIONS**

| *Folder* | *Observation* | *Label* | *Observing Template* | *Science Target* |
|---|---|---|---|---|
| Sunburst IFU | | | | |
| | 1 | IFUGROUP | NIRSpec IFU Spectroscopy | (10) Group COMBINEDIFU |
| Sunburst NIRCam Imaging | | | | |
| | 3 | | NIRCam Imaging | (9) SUNBURSTFULL |

**ABSTRACT**

How the early Universe was reionized is a key science case for JWST. The majority of ionizing Lyman Continuum (LyC) photons were produced by massive stars in the first galaxies, and had to find their way through the neutral ISM and escape into intergalactic Space. How this happened is unclear, and due to the high fraction of neutral gas in the IGM, we cannot study ionizing escape directly at z>4, but must rely on lower redshift analogs.

In the local Universe, escape fractions are far too low to account for the energy needed to cause reionization. In order to determine which physical processes regulate ionizing escape, and how they can evolve over cosmic time, we need to study the ISM of leaking galaxies in high detail, across Cosmological epochs.

We propose deep NIRSpec IFU observations and supplementary NIRCam imaging of the gravitationally lensed “Sunburst Arc” (z=2.4), the only galaxy at z>0.1 for which such a study is possible. The galaxy is an extremely bright LyC leaker, and despite its enormous distance, the only known galaxy where the origin of LyC is pinpointed down to ~10 pc. The proposed observations will enable detailed mapping of the production sites of ionizing radiation, as well as possible escape paths, and detailed mapping of kinematics, ionization and other parameters that will reveal which mechanisms regulate the escape, and how they differ from the local Universe.

These observations will be a unique connecting link between local analogs and the Epoch of Reionization, and will be a valuable reference dataset long after the end of JWST’s mission.

**OBSERVING DESCRIPTION**

This proposal consists of NIRSpec IFU and supplementary NIRCam imaging observations of one target, the gravitationally lensed arc PSZ1-ARC G311.6602–18.4624, nicknamed the Sunburst Arc, a bright and well resolved Lyman-Continuum leaker at redshift ~2.4. The primary science goal is to analyze and understand the astrophysical processes that facilitate the ionizingh escape as a cosmological bridge between local analogs and the Epoch of Reionization.

IFU observations

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Pointings:

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3 pointings have been selected with the NIRSpec IFU to cover regions of particular interest in the de-lensed source.

- Pointing 1: Covers a large part of the de-lensed source with modest distortion

- Pointing 2: Covers regions of extreme magnification, including a possible stellar source which can be studied in detail. Distortion is strong, but the pointing contains a level of detail not attainable elsewhere int he arc.

- Pointing 3: Covers dual mirror images of the Lyman-continuum leaking star cluster and its closest surrounding in very high magnification and with the axis of distortion largely perpendicular to the other pointings, adding significant levels of 2D information.

Spectral settings:
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- G140H/F100LP covers the approximate rest-frame interval  2800Å-5600Å at a resolving power of ~100 km/s, covering important diagnostic lines like the [O II] 3727+3729 doublet, the Balmer series except H-alpha, and the [He II] 4686 feature. Accurate mapping of kinematics is key to this project, for which purpose the high resolving power setting was chosen.

- G235H/F170LP covers the approximate rest frame wavelength interval 4930Å-9200Å, reaching from [O III] 4959 to the [S III] 9069 feature.

Exposure times:
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To reach our science goals, we request 4 pointings of 4 dithered exposures uin each of the two spectral settings.
This leads to the following exposure times:

- G140H/F100LP: 20 groups per integration, 1 integration per exposure, 4 exposures per specification. In total 23575 seconds of exposure time.

- G235H/F170LP: 12 groups per integration, 2 integrations per exposure, 4 exposures per specification. In total 28477 seconds of exposure time.

This adds up to a total of 58368 s on-source, 76779 of charged time.

The NRSSIRS2 readout pattern is used in order to avoid excessive data volume.

Nod and dither patterns:
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With an extended source of unknown total extent, we have opted for the off-source nod strategy for background correction. In accordance with JWST hel desk, we have planned one off-source pointing in a target group with the three on-source pointings. Each pointing uses a standard 4-point subpixel dither to properly sample the PSF in both principal directions.

NIRCam imaging:
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We request imaging in the filters F115W, F150W, F200W, F277W, F356W, and F444W, in three pair exposures.

We request the INTRAMODULE dither pattern with 4 primary dithers á 2 subpixel dithers.

Each exposure consists of 1 integration with 10 groups, using the BRIGHT2 readout pattern.

The exposure time in total amounts to 5160 s on source, 11960 seconds charged in total.

**Fixed Targets**

| # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous |
|---|---|---|---|---|
| (1) | SUNBURST-POS1 | RA: 15 50 4.8300 (237.5201250d)<br>Dec: -78 10 59.30 (-78.18314d)<br>Equinox: J2000 | | |
| *Comments:*<br>*Category=Galaxy*<br>*Description=[Emission line galaxies, High-redshift galaxies, Irregular galaxies, Lyman-alpha galaxies, Starburst galaxies]*<br>*Extended=YES* | | | | |
| (2) | SUNBURST-POS2 | RA: 15 50 0.6000 (237.5025000d)<br>Dec: -78 11 9.90 (-78.18608d)<br>Equinox: J2000 | | |
| *Comments:*<br>*Category=Galaxy*<br>*Description=[Irregular galaxies, Lyman-alpha galaxies, Starburst galaxies]* | | | | |
| (3) | SUNBURST-POS3 | RA: 15 49 59.9700 (237.4998750d)<br>Dec: -78 11 12.90 (-78.18692d)<br>Equinox: J2000 | | |
| *Comments:*<br>*Category=Galaxy*<br>*Description=[Emission line galaxies, High-redshift galaxies, Lyman-alpha galaxies, Starburst galaxies]* | | | | |
| (4) | SUNBURST1SKY | RA: 15 50 4.6401 (237.5193338d)<br>Dec: -78 11 4.67 (-78.18463d)<br>Equinox: J2000 | | |
| *Comments:*<br>*Category=Calibration*<br>*Description=[External flat field, Telescope/sky background]*<br>*Extended=YES* | | | | |
| (9) | SUNBURSTFULL | RA: 15 50 6.0000 (237.5250000d)<br>Dec: -78 11 25.00 (-78.19028d)<br>Equinox: J2000 | | |
| *Comments:*<br>*Category=Galaxy*<br>*Description=[Brightest cluster galaxies, Emission line galaxies, Lyman-alpha galaxies, Starburst galaxies]*<br>*Extended=YES* | | | | |
| (10) | Group COMBINEDIFU | | | |
| *Comments:*<br>*Target Selection=[1 SUNBURST-POS1, 2 SUNBURST-POS2, 3 SUNBURST-POS3, 4 SUNBURST1SKY]* | | | | |

## Observation

**Proposal 2555, Observation 1: IFUGROUP** Wed Mar 15 21:00:59 GMT 2023

**Diagnostic Status: Warning**

Observing Template: NIRSpec IFU Spectroscopy

Background Observations:[]

## Diagnostics

(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 1:1) Warning (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.

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous |
|---|---|---|---|---|
| (10) | Group COMBINEDIFU | | | |

*Comments:*
*Target Selection=[1 SUNBURST-POS1, 2 SUNBURST-POS2, 3 SUNBURST-POS3, 4 SUNBURST1SKY]*

## Template

| TA Method |
|---|
| NONE |

## Dithers

| # | Dither Type | Size | Starting Point | Number of Points | Points |
|---|---|---|---|---|---|
| 1 | 4-POINT-DITHER | | | | |

## Spectral Elements

| # | Grating/Filter | Readout Pattern | Groups/Int | Integrations/Exp | Leakcal | Dither | Autocal | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | G140H/F100LP | NRSIRS2 | 20 | 1 | false | true | NONE | 4 | 4 | 5893.912 | |
| 2 | G235H/F170LP | NRSIRS2 | 15 | 2 | false | true | NONE | 4 | 8 | 8870.045 | |

## Special Requirements

Aperture PA Range 81.97253418 to 94.97253418 Degrees (V3 303.0 to 316.0)

## Observation

**Proposal 2555, Observation 3** Wed Mar 15 21:00:59 GMT 2023

**Diagnostic Status: Warning**

Observing Template: NIRCam Imaging

## Diagnostics

(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

(Visit 3:1) Warning (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.

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous |
|---|---|---|---|---|
| (9) | SUNBURSTFULL | RA: 15 50 6.0000 (237.5250000d)<br>Dec: -78 11 25.00 (-78.19028d)<br>Equinox: J2000 | | |

*Comments:*
*Category=Galaxy*
*Description=[Brightest cluster galaxies, Emission line galaxies, Lyman-alpha galaxies, Starburst galaxies]*
*Extended=YES*

## Template

| Module | Subarray | Target Placement |
|---|---|---|
| B | FULL | Module Gap |

## Dithers

| # | Primary Dither Type | Primary Dithers | Subpixel Dither Type | Dither Size | Subpixel Positions |
|---|---|---|---|---|---|
| 1 | INTRAMODULEBOX | 4 | STANDARD | | 2 |

## Spectral Elements

| # | Short Filter | Long Filter | Readout Pattern | Groups/Int | Integrations/Exp | Total Integrations | Total Dithers | Total Exposure Time | ETC Wkbk.Calc ID |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F115W | F277W | BRIGHT2 | 10 | 1 | 8 | 8 | 1717.883 | |
| 2 | F150W | F356W | BRIGHT2 | 10 | 1 | 8 | 8 | 1717.883 | |
| 3 | F200W | F444W | BRIGHT2 | 10 | 1 | 8 | 8 | 1717.883 | |

## Special Requirements

Aperture PA Range 301.05583529 to 349.05583529 Degrees (V3 301.0 to 349.0)
Offset 40.0 arcsec, 20.0 arcsec
Background Limited. Background no more than 10th percentile above minimum