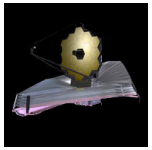
Anatomy of an ionized bubble at z=6.6: Which galaxies reionized the Universe?

Matthee, Jorryt; Naidu, Rohan; Conroy, Charlie; Hutter, Anne; Oesch, Pascal; Pezzulli, Gabriele; Sobral, David; Tacchella, Sandro



1933 - Anatomy of an ionized bubble at z=6.6: Which galaxies reionized the Universe?

Cycle: 1, Proposal Category: GO

INVESTIGATORS

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OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
NIRCam LW WFSS and SW imaging				
	1	COLA1	NIRCam Wide Field Slitless Spectroscopy	(1) COLA1

ABSTRACT

Identifying the sources that drove cosmic reionization is a key goal of observational cosmology. Photons from these sources carved out ionized bubbles in the neutral intergalactic medium, and these bubbles gradually coalesced, resulting in a fully ionized Universe.

The luminous z=6.6 'COLA1' galaxy lies in the epoch of reionization and shows a remarkable, double-peaked Lyman-alpha (Lya) line, the only one confirmed by multiple teams with high SNR and resolution. The detection of Lya flux bluewards of the systemic velocity means COLA1 resides in

an ionized bubble. The exact velocity at which the blue Lya light is cut-off constrains the bubble size. This bubble provides a unique fortuitous, controlled environment -- since the bubble size is constrained, so is the total ionizing flux required to power it. Did COLA1 produce this ionizing flux all by itself? Or is it surrounded by large numbers of bright galaxies? Is a significant contribution from the faintest galaxies necessary?

We propose to blindly identify emission-line galaxies within the ionized bubble and to obtain sensitive spectroscopy of COLA1 itself with slitless grism spectroscopy in the NIRCam F356W filter. The bubble size is well matched to the effective field of view for H-beta and the [OIII] doublet at z=6.6. We will obtain spectroscopic redshifts for all objects brighter than 0.1 L* (SFR>2 Msun/yr) and directly measure their ionizing photon production rate. We will then assess how much contribution from unseen galaxies is required. Through our detailed accounting of ionizing photons we will address the central question to reionization studies: was it bright or faint galaxies that reionized the universe?

OBSERVING DESCRIPTION

This program uses wide field slitless spectroscopy in the R-grism with NIRCam in the F356W filter in the LW module targeting 'COLA1' a strong emission-line galaxy at z=6.6 in an ionized bubble. We will measure Hg, Hb and [OIII]4960,5008 for this galaxy. We will search blindly for line-emitters around COLA1, particularly through the [OIII]4960,5008 doublet which has a relative line-ratio of 1:3 and fixed intrinsic line separation facilitating the source identification in slitless grism data. These measurements will be used to measure the ionizing emissivity of bright galaxies in the ionized bubble around COLA1 and allow us to assess whether a contribution from faint, unseen galaxies is required. We expect to be spectroscopically complete for all emission-line galaxies with luminosity > 0.1L* at z=6.6. Simultaneously we will image in the SW module with the F115W and F200W filters that will allow the characterization of the UV continuum in the identified galaxies.

The program uses a four-visit overlapping mosaic with 70% row overlap and 46% column overlap and -1.2 column shift. Visits need to be performed with the same PA, but there are no restrictions on the specific PA. There are no bright sources in the mosaic regardless of the PA. COLA1 is placed in the center of the effective field of view for redshifted [OIII] at z=6.6. Therefore it lies in an optimal location on the SW detectors. In the LW, we will only use the grism R. The central part (including COLA1 and the majority of the ionized bubble) will be covered by four visits: twice by module A and twice by module B, yielding reversed grism spectra. Another central strip will have reversed spectra as it will be covered by one visit in both modules. The outer parts of the mosaic are covered by 1 or 2 visits from a single module (hence a single dispersion direction) and are less important for our science case. The continuum spectra are not important for our goal and the spectral resolution of the grism will make it possible to associate the detection of the [OIII]4960,5008 emission line pair to a detection on the direct images. In each visit we also take direct images in F356W and two out of field exposures that cover the region outside the spectroscopic field of view. Considering the compromise between data rate and not suffering from cosmic ray impact, we use MEDIUM8 readout patterns with 7 Groups/Int for the grism exposures (3 during F115W and 4 during F200W in

SW) and DEEP8 with 3 Groups/Int for the direct image and out-of field exposures. Per visit the total exposure is 3607s in F115W and 4895s in F200W, and 8502s in the LW grism image. The F200W data will be deeper than the F115W data to optimise the legacy value of these data.

As COSMOS is a legacy field, we propose to waive the proprietary time on the SW imaging data (F115W and F200W) of our program.

Proposal 1933 - Targets - Anatomy of an ionized bubble at z=6.6: Which galaxies reionized the Universe?

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	COLA1	RA: 10 02 35.3800 (150.6474167d) Dec: +02 12 13.96 (2.20388d) Equinox: J2000	Epoch of Position: 2015.5	

Comments: Redshift 6.591
Category=Galaxy
Description=[Emission line galaxies, High-redshift galaxies]
Extended=NO

Observation

Proposal 1933, Observation 1: COLA1

Tue Mar 30 21:05:21 GMT 2021

Diagnostic Status: Warning

Observing Template: NIRCam Wide Field Slitless Spectroscopy

Diagnostics

(COLA1 (Obs 1)) Warning (Form): Use of only one of GRISMR or GRISMC may result in spectral overlap from multiple sources that can't be corrected. Users should address this issue in their proposal text.

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

(Visit 1:2) Warning (Form): Overheads are provisional until the Visit Planner has been run.

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

(Visit 1:4) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

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Comments: Redshift 6.591
Category=Galaxy
Description=[Emission line galaxies, High-redshift galaxies]
Extended=NO

Template

Module	Subarray	Grism (Long Wavelength)
ALL	FULL	GRISMR

Mosaic

Rows	Columns	Row Overlap %	Column Overlap %	Row shift	Column shift	Tile Order
2	2	70.0	46.0	0.0	-1.2	DEFAULT

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Positions
1	INTRAMODULEX	3	4-Point

Direct Image

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	Grism (Long Wavelength)	Exposure Type	Total Dithers
1	F200W	F356W	DEEP8	3	1	1	515.365	39119	GRISMR	Direct Image	1

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID	Grism (Long Wavelength)	Exposure Type	Total Dithers
1	F115W	F356W	MEDIUM8	3	1	12	3607.555	39119	GRISMR	Grism (Long Wavelength)	12
2	F200W	F356W	MEDIUM8	4	1	12	4895.967	39119	GRISMR	Grism (Long Wavelength)	12
3	F200W	F356W	DEEP8	3	1	2	1030.73	39119		Out of Field	2

Special Requirements	
	Group Visits within 53.0 Days Visits Same PA Offset 4.0 arcsec, -3.5 arcsec