14495 - The gas-metallicity and the ISM of the brightest Lyman-alpha emitter at z=6.6: metal-free?

Cycle: 23, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) CR7	WFC3/IR	3	22-Apr-2016 21:03:33.0	yes
02	(1) CR7	WFC3/IR	2	22-Apr-2016 21:03:36.0	yes

5 Total Orbits Used

ABSTRACT

We have recently discovered the most luminous Lyman-alpha (Lya) emitter ever found in the era of re-ionization ('CR7', z = 6.6, L(Lya)=10^43.9 erg/s; Sobral et al. 2015, ApJ, 808, 139), with extreme Lya rest-frame EW (>200A). Ground-based near-infrared spectroscopy reveals the presence of a strong HeII164nm emission line with narrow FWHM (~130 km/s), high rest-frame EW (~80 A) and the absence of metal lines down to limits which have never been seen before (e.g. HeII/CIII]>2.5 and HeII/OIII]>3.0). Current ground-based data, limited by atmospheric OH lines, already imply a metallicity of at least <0.003 solar and exclude 'normal' AGN. CR7 must therefore host a unique, very hot ionising source (~100kK or higher), which may be explained by i) very low metallicity WR stars, ii) a direct collapse black hole (DCBH) or iii) a PopIII-like stellar population. HST/WFC3 observations reveal that i) CR7 consists of three components (A, B, C) which are separated by ~5 projected kpc and ii) the brightest (A) coincides with the Lya peak and HeII emission. Our new CLOUDY modelling exploring a wide physical parameter space clearly shows that high ionisation N, O and C lines can place strong constraints on the metallicity and physical conditions of the ionised ISM of CR7. Only WFC3 Grism observations on HST can achieve the required sensitivies to test if CR7 is "metal free" (<10^-4 solar). Constraining the metallicity and the ionised ISM is absolutely key towards unveiling the nature of this source and its ISM, testing both the PopIII and DCBH interpretations.

OBSERVING DESCRIPTION

We aim to use the unique capabilities of WFC3 to further unveil the nature of CR7 by looking for faint metal lines which can be compared directly with the strong HeII1640 emission. We will use the WFC3 grism to look for any weak emission line which could be an indication that the source is not completely metal-free (or obtain stringent line limits that will imply that the source needs to be completely metal-free). The 141 Grism has the necessary resolution (R~130 at 1.1-1.6 um) to separate all our target lines at z=6.6.

Exposure times:

We use the WFC3IR spectroscopic exposure time calculator to find that in order to achieve our science goals with the WFC3 grism (detect any of NIV1487, CIV1549, OIII]1664, NIII]1750 and CIII]1909 with >0.4x10^-17 erg/s/cm^-2; 3 sigma), we require 12.8 ks. Note that this means that if all lines apart from HeII remain undetected, at the 1 sigma level, the source must be virtually metal free. Observations with the WFC3 grism will consist (our target is visible for 54 minutes per orbit) of a guide-star acquisition (6 min), two un-dispersed science exposures (4.8 minutes) and one science exposure of 40 minutes (per orbit). Filter changes, camera set-ups and readouts will add an extra 4.8 minutes. Thus, in order to achieve the necessary

S/N, we require 5 orbits with the WFC3 grism. We will assure (with our WFC3 imaging) that the dispersed light does not overlap with any bright source in the field of view, and that we disperse it in angles which also avoid the overlap of components within CR7 (PA angles 28+-180 and 97+-180).

Angles needed to avoid/minimise contamination:

We will observe the source with 2 different dispersion angles of 28 and 97 deg. We assume these to be PA_DISPERSION angles.
We thus compute, for WFC/IR grism ORIENT = (PA_DISPERSION+225.37). This results in ORIENT angles of i) 253.37 (73.37 also possible - dispersion on the opposite direction but along the same angle) and ii) 322.37 (142.37 with the dispersion in the opposite direction).

Orbit / visit strategy:

Each visit consists of 2 orbits + a final one. In these 2 orbits 4 dithered exposures in WFC3/G141 will be obtained, along with 4 direct images taken at the same positions. We follow the simple pattern

direct, grism, offset, direct, grism, offset, ...

Dithering strategy:

We use POS-TARG offsets to enable rejection of hot/bad pixels and to improve sampling of the PSF. The pattern is:

POS-TARG: (0,0) (1.355,0.424) (0.881,1.212) (-0.474,0.788)
pixels: (0,0) (10.0,3.5) (6.5,10.0) (-3.5,6.5)

This is a larger version of the standard WFC3-IR-DITHER-BOX-MIN pattern, which has only 1-2 pixel offsets between pointings. As some bad pixels come in clumps we prefer a slightly larger pattern. No attempt is made to dither over the "dead spot", as large dithers introduce large differential distortion.

Fluxes:

We already know the relevant flux-densities accurately (and many limits), allowing for an accurate estimate of the exposure times without uncertain extrapolations. For our grism observations, the most relevant information is the HeII1640A line-flux:4x10^-17 erg/s/cm^-2. From our X-SHOOTER observations (Sobral et al. 2015), we already have some strong line limits, such as HeII/CIII]1909>2.5 and HeII/OIII]1663>3. We aim to improve these limits by at least a factor of ~3-4, to reach line limits between HeII and lines such as NIV1487, CIV1549, OIII]1664, NIII]1750 and CIII]1909 of >10 (3 sigma) - all separated at the resolution of the grism at z=6.6. Given the strong ionising source, if all these lines are undetected at that level, the source must be virtually metal-free. In order to achieve such limits, we require to detect any emission line with >0.4x10^-17 erg/s/cm^-2 from 1.10-1.65um at >3 sigma. Our observations will also result in a HeII >50 sigma detection, sufficient to characterise its spatial extent and deep enough to look for any emission from clumps B and C in CR7 (our ALMA observations will also provide key information for those). We note that because we already have WFC3 imaging, we can assure the best choice of dispersion angles that assure that sources do not overlap with the three clumps and that the clumps do not overlap between themselves (PA angles 28+-180 and 97+-180).

Visit

Proposal 14495, Visit 1 (01), implementation Sat Apr 23 01:03:37 GMT 2016

Diagnostic Status: Warning

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT 72.37D TO 74.37 D

Diagnostics

(Visit 1 (01)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE

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(Visit 1 (01)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE

Fixed Targets

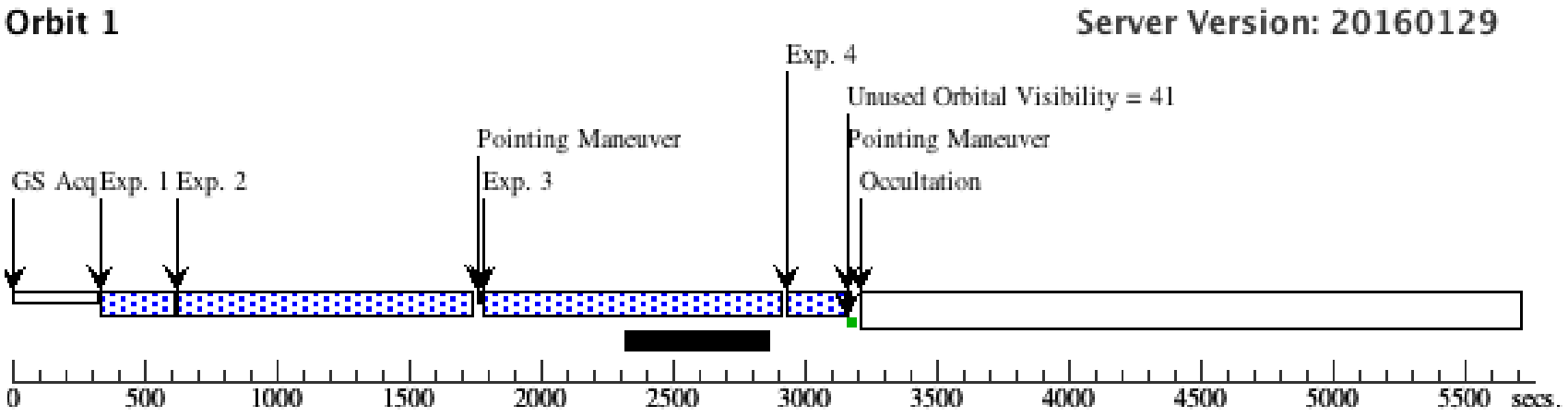
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	CR7	RA: 10 00 58.0050 (150.2416875d) Dec: +01 48 15.25 (1.80424d) Equinox: J2000		V=(?) f_Lya = 1.7e-16 erg/s/cm2, f_heII1640 = 4e-17 erg/s/cm2	Reference Frame: ICRS

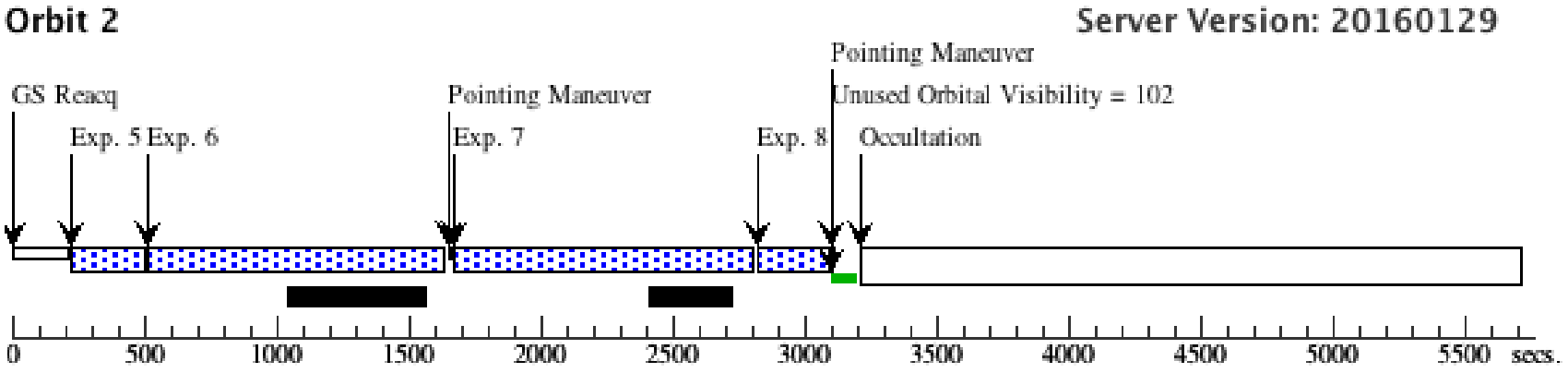
Comments: Extended=YES

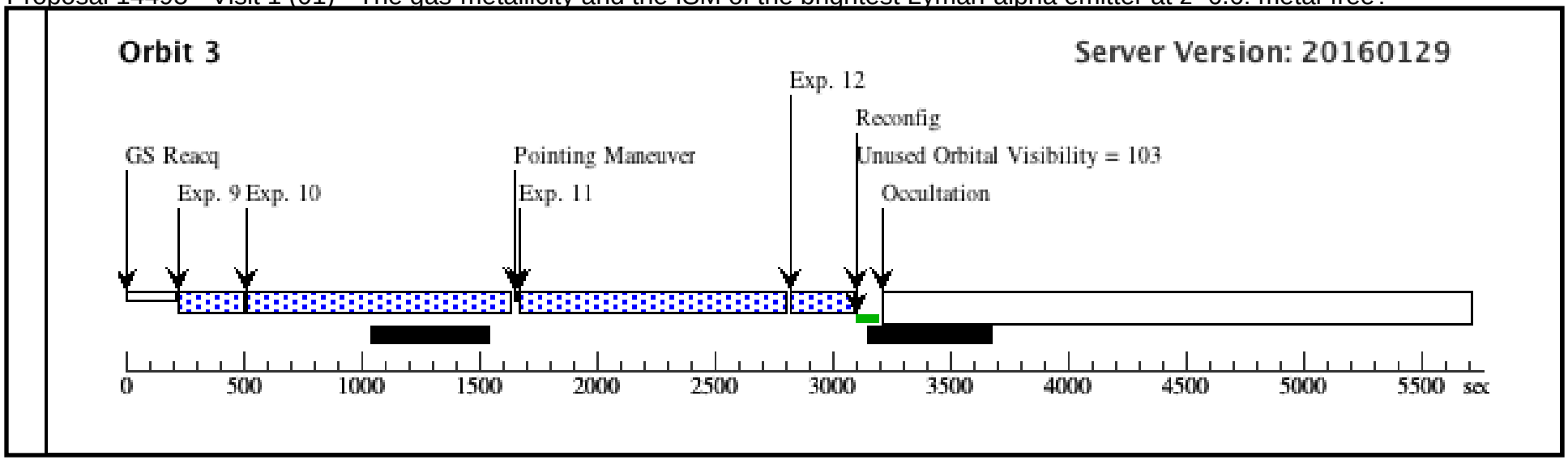
Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	POS TARG 0,0; GS ACQ SCENARIO BASE1B3	Sequence 1-4 Non-Int in Visit 1 (01)	252.934546 Secs (252.935 Secs) *[==>]*	***[1]***
2	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	SAME POS AS 1	Sequence 1-4 Non-Int in Visit 1 (01)	1102.935844 Secs (1102.936 Secs) *[==>]*	***[1]***
3	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	POS TARG 1.355,0.424	Sequence 1-4 Non-Int in Visit 1 (01)	1102.935844 Secs (1102.936 Secs) *[==>]*	***[1]***
4	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=5; SAMP-SEQ=SPARS50	SAME POS AS 3	Sequence 1-4 Non-Int in Visit 1 (01)	202.934095 Secs (202.934 Secs) *[==>]*	***[1]***
5	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	POS TARG 0.881,1.212	Sequence 5-8 Non-Int in Visit 1 (01)	252.934546 Secs (252.935 Secs) *[==>]*	***[2]***
6	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	SAME POS AS 5	Sequence 5-8 Non-Int in Visit 1 (01)	1102.935844 Secs (1102.936 Secs) *[==>]*	***[2]***
7	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	POS TARG -0.474,0.788	Sequence 5-8 Non-Int in Visit 1 (01)	1102.935844 Secs (1102.936 Secs) *[==>]*	***[2]***
8	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	SAME POS AS 7	Sequence 5-8 Non-Int in Visit 1 (01)	252.934546 Secs (252.935 Secs) *[==>]*	***[2]***
9	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	POS TARG 0.271,0.242	Sequence 9-12 Non-Int in Visit 1 (01)	252.934546 Secs (252.935 Secs) *[==>]*	***[3]***
10	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	SAME POS AS 9	Sequence 9-12 Non-Int in Visit 1 (01)	1102.935844 Secs (1102.936 Secs) *[==>]*	***[3]***
11	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	POS TARG -0.203,-0.181	Sequence 9-12 Non-Int in Visit 1 (01)	1102.935844 Secs (1102.936 Secs) *[==>]*	***[3]***
12	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	SAME POS AS 11	Sequence 9-12 Non-Int in Visit 1 (01)	252.934546 Secs (252.935 Secs) *[==>]*	***[3]***

Orbit Structure



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Pointing Maneuver
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Exp. 9
Exp. 10
Exp. 11
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2500
3000
3500
4000
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5000
5500
sec

Visit

Proposal 14495, Visit 2 (02), implementation Sat Apr 23 01:03:37 GMT 2016

Diagnostic Status: Warning

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT 140.37D TO 144.37 D; ORIENT 321.37D TO 323.37 D

Diagnostics

(Visit 2 (02)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE

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Comments: Extended=YES

Exposures

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1	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	POS TARG 0,0	Sequence 1-4 Non-Int in Visit 2 (02)	252.934546 Secs (252.935 Secs) *[==>]*	*[1]*
2	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	SAME POS AS 1	Sequence 1-4 Non-Int in Visit 2 (02)	1102.935844 Secs (1102.936 Secs) *[==>]*	*[1]*
3	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	POS TARG 1.355,0.424	Sequence 1-4 Non-Int in Visit 2 (02)	1102.935844 Secs (1102.936 Secs) *[==>]*	*[1]*
4	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=5; SAMP-SEQ=SPARS50	SAME POS AS 3	Sequence 1-4 Non-Int in Visit 2 (02)	202.934095 Secs (202.934 Secs) *[==>]*	*[1]*
5	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	POS TARG 0.881,1.212	Sequence 5-8 Non-Int in Visit 2 (02)	252.934546 Secs (252.935 Secs) *[==>]*	*[2]*
6	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	SAME POS AS 5	Sequence 5-8 Non-Int in Visit 2 (02)	1102.935844 Secs (1102.936 Secs) *[==>]*	*[2]*
7	Exposure_Grism	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	G141	NSAMP=12; SAMP-SEQ=SPARS100	POS TARG -0.474,0.788	Sequence 5-8 Non-Int in Visit 2 (02)	1102.935844 Secs (1102.936 Secs) *[==>]*	*[2]*
8	Exposure_Imaging	(1) CR7	WFC3/IR, MULTIACCUM, GRISM1024	F140W	NSAMP=6; SAMP-SEQ=SPARS50	SAME POS AS 7	Sequence 5-8 Non-Int in Visit 2 (02)	252.934546 Secs (252.935 Secs) *[==>]*	*[2]*

Orbit Structure