Rationale for DD-ERS Program

Executive Summary

1. Justification for ERS time
Our Directors Discretionary time for an Early Release Science (DD-ERS) program will help the community learn about the longest wavelength spectrograph on the *James Webb Space Telescope (JWST)*, the Mid-Infrared Instrument (MIRI) Medium-resolution spectrometer (MRS). We will release a suite of science-enabling products (SEPs) via a public data analysis and code repository that we have already begun to build: `github.com/miri-mrs`. The accompanying documentation is also already being written: `miri-mrs.readthedocs.io`. *Our primary SEP goal is to produce a Python package that quickly manipulates and analyzes the full MRS Level 3 data, in particular the MRS Spectral Cubes and 1D spectra.*

2. Project Management Plan & Budget
Our team members have a long and proven history of delivering SEPs, catalogs, data products, web access pages, documentation and the necessary helpdesk support for large collaborations on strict deadlines. Our project is led by a STFC Ernest Rutherford Senior Research Fellow, who is able to contribute 100% FTE to the development, delivery and management of the SEPs. We also ask for support for two postdoctoral researchers who will be in place at Launch time.

3. Scientific Justification
Our science case is straight-forward, yet strikes at the heart of a major and still open extragalactic astrophysical question: *What are the star-formation properties of mid-infrared luminous quasars at the peak of quasar activity?* We will answer this by looking for the presence of polycyclic aromatic hydrocarbon (PAH) spectral features in $z \approx 2.5$ infrared bright quasars. Furthermore, we will use the IFU capability of MIRI MRS in order to quantify the spatial location of the IR luminosity. This is an ideal investigation for *James Webb*; no other current or near-future facility, ground or space-based, has the combination of MIR spectroscopy, angular resolution and the sensitivity required for accessing the PAH spectral features at $z > 2$, *and* being able to spatial resolve their structure.

4. Description of the Targets
We have four primary targets; all are available for early observation. We also have a back-up list of ten secondary targets, any of which would allow us to achieve our SEP and Science goals. These fourteen objects have extensive associated multiwavelength data with our four primary targets known to exhibit interesting kinematic behavior.

5. Team Diversity
Our team is an ensemble of observational extragalactic experts with a broad geographical dispersion. This is a new collaboration, but with substantial heritage and expertise from the SDSS, the *HST/Chandra* Deep Field surveys, and more recent ground-based IR IFU collaborations (e.g., VLT/KMOS). Our team currently has a gender binary split of 7:12 (37:63) F:M. It is predominantly White European or White American.

Science Rationale

Over 50 years after their formal identification, and over two decades since the calculation of their space density evolution, several fundamental facts remain unknown for high-luminosity AGN, i.e. quasars: What is the main AGN triggering mechanism at the height of quasar activity at redshifts $z = 2-3$? What direct observational evidence in individual objects links AGN activity to star formation? Can we observe "AGN feedback" in action, in situ, for the most luminous sources at their peak activity? Such unknowns about the co-evolution of black holes and their host galaxies remain among the most fundamental unanswered questions in extragalactic astronomy. And they will be answered with the launch of the *James Webb Space Telescope.*

We have identified a population of obscured, mid-infrared bright quasars at the peak of cosmological quasar activity. These sources are mid-IR luminous and may be powered by major bursts of star formation tied to an early phase of galaxy evolution/formation. However, their global star-formation properties are currently unknown. Observations with *JWST* MIRI, and in particular MRS spectroscopy, will quantify the level of star-formation in these objects. *We will observe four "extremely red" quasars with MIRI MRS across the full wavelength range to high signal to noise.* These observations will address the fundamental question of the link between star-formation and AGN activity, at the cosmological epoch for both of these processess; an investigation *JWST* was specifically built for.

It is unknown whether the large IR luminosities observed in these quasars is from star formation, which would produce strong polycyclic aromatic hydrocarbon (PAH) spectral features, or, if it is from the hot dust near the central quasar, which should produce much weaker/no PAH emission (due to the AGN MIR emission diluting and even destroying PAH features). *Via the detection, or otherwise, of PAH spectral features, we will measure the SFRs during what is potentially a very early/obscured stage of massive galaxy formation in the extremely red quasar population.*

MIRI MRS is the instrument of choice since no other spectrometer on *JWST* observes longward of 5.3μm; going redder than this is crucial in order to detect PAH features in $z > 2$ objects. If present we will observe the most prominent, well-known major PAH emission features at 3.3, 6.2, 7.7, and 8.6μm. The mid-IR spectral region also presents a suite of high-ionization lines and critically, we will have access to the [Ne VI] 7.65μm line which can be used to measure the instantaneous luminosity of the central engine. *The desire to immediately gain high signal-to-noise spectra in order to investigate the physics and chemistry of quasar PAHs, along with observational overhead concerns, pushes us to observe each object for 3.6 hours, for a total program Charged Time of 22.20 hours.*

Community Access Rationale

We have already begun to design and create science-enabling products (SEPs) to help the community understand JWST's capabilities. Our MIRI MRS Repo `github.com/miri-mrs` is active and completely accessible to anyone in the broader community. The accompanying documentation is also already being written: `miri-mrs.readthedocs.io`. *Our primary SEP goal is to produce a Python package that quickly manipulates and analyzes the full MRS Level 3 data, in particular the MRS Spectral Cubes and 1D spectra.* We note there is already Python legacy code for this type of analysis: `spectral-cube.readthedocs.io`. *Critically, we have already begun working closely with the MIRI team (due to the P.I.'s location at Edinburgh) and will continue to develop tools here for the MIRI MRS.*

Our timeline has delivery of the first set ('beta') of MIRI MRS SEPs before the Cycle 1 GO Deadline (March 2018); our v1.0.0 (with e.g. MIRSim mock data) before the launch of JWST (October 2018) and then rapid version updates once the start of science operations commences in April 2019.

With *a maximum* of 6 months between the first ERS observations and the Cycle 2 GO Call for Proposals, this will likely be too short for full dissemination of our findings, novel techniques and science results in the traditional manner, i.e. via published journal articles. Moreover, ongoing updated versions of our analyses and codes are envisaged to happen until right up to the Cycle 2 deadline. To solve these issues, we will fully employ the power of a code version repository system, in our case GitHub, to keep the community informed and updated with our SEPs. GitHub *has code versioning automatically built-in* so proper referencing of e.g. technical notes is straight-forward.

Our team's commitment to an open access ideology, not only for data, but for analysis codes, documentation, and scientific manuscripts is already evident and in place, for an example, see the P.I.'s GitHub `/github.com/d80b2t`. We are thus extremely well-placed to satisfy the overall goals of the DD ERS program. ensure open access to representative datasets in support of the preparation of Cycle 2 proposals, and engage a broad cross-section of the astronomical community in familiarizing themselves with JWST data and scientific capabilities.

■ Scientific Justification

One lasting scientific legacy of the *Hubble Space Telescope (HST)* is the discovery of massive black holes at the centers of a substantial fraction of galaxies, confirming the longstanding theory of the "central engines" of quasars. One of the major surprises from the *Hubble* was the discovery of a strong correlation between black hole mass and host galaxy properties.[1] This connection, causal or otherwise, may provide crucial clues to how and why these black holes formed and how their host galaxies evolved. *As of the launch of the James Webb Space Telescope (JWST), the question of how black holes affect their host galaxies is one of the outstanding questions in astrophysics.*

Observational and theoretical work now suggests that active galaxies and black holes are potentially linked to both the triggering, and "quenching", of massive star formation. The

[1]Assessment of Options for Extending the Life of the Hubble Space Telescope: Final Report (2005); https://www.nap.edu/read/11169/chapter/5).

link between massive galaxies and the central super-massive black holes (SMBHs) that appear ubiquitous is vital to the understanding of galaxy formation and evolution, and significant observational and theoretical effort has been invested in trying to measure and understand the physics involved in these systems. The two main energy sources available to a galaxy are nuclear fusion in stars and gravitational accretion onto compact objects, and we still do not fully understand the interaction of an active galactic nuclei and the star formation properties of their host galaxies.

The "quenching" of galaxy-wide star formation is supposedly driven by " AGN feedback", where the AGN heats the surrounding gas corona, offsetting cooling losses and disrupting the gas inflow. This feedback manifests itself as high-velocity outflows from the AGN. However, *direct observational evidence* for AGN feedback is conspicuous by its absence. This statement is especially true at high-z, e.g. $z = 2 - 3$, at the height of the Quasar Epoch. We have identified the best candidates that would possess quasar feedback in action, in situ at high-redshift. These are the "Extremely Red Quasars" identified via their WISE W3/4 colors. As such, these mJy luminous AGN *are ideal targets for JWST MIRI.*

The Extremely Red Quasar Population

Extremely Red Quasars (ERQs) are a unique obscured quasar population with extreme physical conditions related to powerful outflows across the line-forming regions. These sources are the signposts of the most extreme form of quasar feedback at the peak epoch of galaxy formation, and may represent an active "blow-out" phase of quasar evolution.

By matching the quasar catalogues of the Sloan Digital Sky Survey (SDSS) and the Baryon Oscillation Spectroscopic Survey (BOSS) to the Wide-Field Infrared Survey Explorer (WISE), Ross et al. (2015) discovered quasars with extremely red infrared-to-optical colors: $r_{\rm AB} - W4_{\rm Vega} > 14$ mag, i.e., $F_\nu(22\mu{\rm m})/F_\nu(r) \gtrsim 1000$; see Figure 1. These objects have infrared luminosities $\sim 10^{47}$ erg s^{-1}, and this initial study returned a heterogeneous population, spanning a wide redshift range $0.28 < z < 4.36$.

Hamann et al. (2017) refined the selection of the ERQs, homing the definition based on additional analysis and common properties, and found several more objects in this new scheme. The ERQs have a suite of peculiar emission-line properties including large rest equivalent widths (REWs), unusual "wingless" line profiles, large N V/Lyα, N V/C IV, Si IV/C IV and other flux ratios, and very broad and blueshifted [[O III]] λ5007 (e.g., Figure 1, top right).

Our team has identified a core sample of 97 ERQs with nearly uniform peculiar properties selected via i–$W3 \geq 4.6$ (AB) and REW(C IV) ≥ 100 Å at redshifts 2.0–3.4. The core ERQs have median luminosity $\langle \log L({\rm ergs/s}) \rangle \sim 47.1$, sky density 0.010 deg^{-2}, surprisingly flat/blue UV spectra given their red UV-to-mid-IR colors, and common outflow signatures including BALs or BAL-like features and large C IV emission-line blueshifts. Their SEDs (see Figure 2) and line properties are inconsistent with normal quasars behind a dust reddening screen. Patchy obscuration by small dusty clouds could produce the observed UV extinctions without substantial UV reddening.

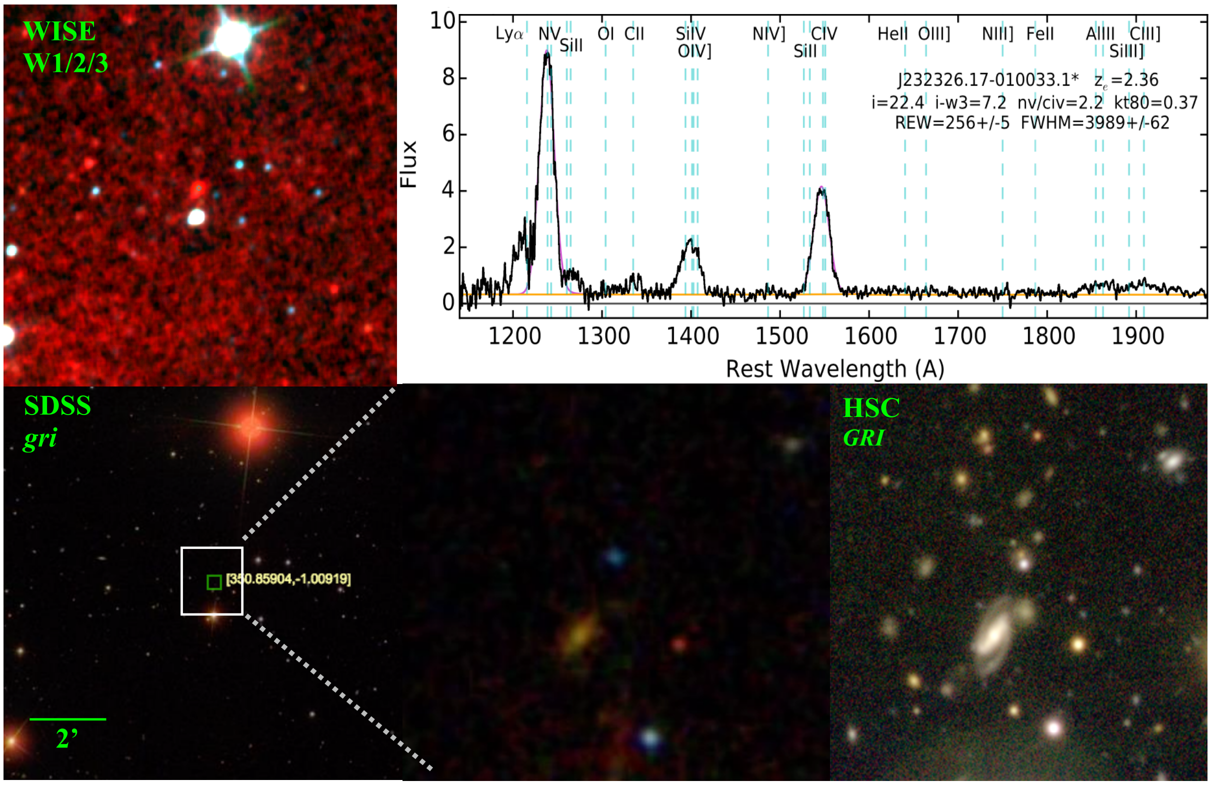

Figure 1. IR and optical imaging of J2323-0100, one of the four Extremely Red Quasar ERS targets. WISE (*top left*), SDSS (*bottom left*) with zoom-in (*bottom center*) and new HSC imaging (*bottom right*). The UV-rest frame spectrum (from Hamann et al. 2017) is given in the top right. Emission lines are labelled at positions marked by dashed blue lines. Note the unusual line flux ratios e.g., N V>Lyα and large N V /C IV. The orange and magenta curves show our fits to the continuum, and the C IV and N V emission lines, respectively. The redshift and other measured properties are also given.

Further observations by our team with VLT/XShooter measured rest-frame optical spectra of four of the $z \sim 2.5$ ERQs (Zakamska et al. 2016) which revealed very broad (FWHM = 2600-5000 km s^{-1}), strongly blue-shifted (by up to 1500 km s^{-1}) [O III] λ5007Å emission lines in these objects. In a large sample of type 2 and red quasars, [O III] kinematics are positively correlated with infrared luminosity, and the four objects in our sample are on the extreme end both in [O III] kinematics and infrared luminosity. As such, we estimate that at least 3% of the bolometric luminosity in these objects is being converted into the kinetic power of the observed wind. Photo-ionization estimates suggest that the [O III]emission might be extended on a few kpc scales, which would suggest that the extreme outflow is affecting the entire host galaxy of the quasar.

Given the extreme nature of these objects, especially in the kinematics, what is the power source for the IR luminosity? Is it young, hot stars in a starburst, or hot dust powered by the central AGN? Furthermore, how, if at all, is this IR emission connected to the conditions at large of the quasar and host galaxy?

MIR spectroscopy: In order to quantify the main energy contribution in galaxies, one needs to differentiate objects powered by nuclear fusion in stars from objects powered by mass accretion onto supermassive black holes. MIR spectroscopy allows the detection of obscured

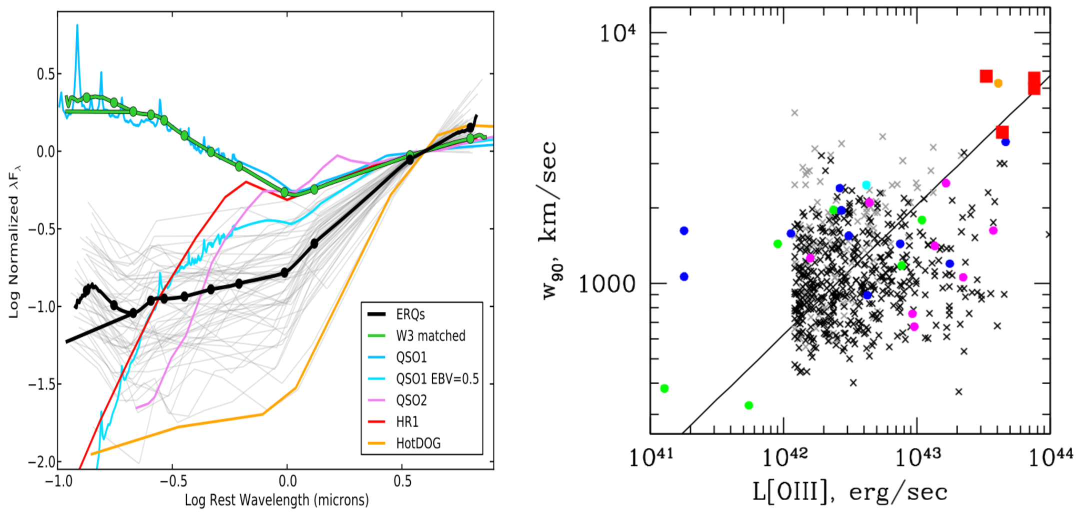

Figure 2: *(Left)* From Hamann et al., 2017, the normalized median SEDs for Type 1 non-BALs in the core ERQ sample (black curve) plus blue quasars matched to the core ERQs in W3 magnitude (green curve). The Type 1 quasar template with and without reddening equal to $E(BV) = 0.5$ (light blue, 'QSO1', from Polletta et al. 2007), a typical Type 2 quasar from Mateos et al. (2013; 'QSO2', purple), a typical heavily reddened Type 1 quasar from Banerji et al. (2013; 'HR1'), and a typical HotDOG from Tsai et al. (2015). The light grey curves are SEDs of individual core ERQs. *(Right)* [O III] kinematics as a function of luminosities for our four targets, red squares, with other quasar populations are shown by black points and various colored symbols. At these extreme velocities, the gas cannot be confined by any realistic galaxy potential and is thus likely to escape from the galaxy; these objects are likely signposts of the extreme blow-out phase of quasar feedback observed at the peak epoch of galaxy formation.

AGN components even when the MIR is dominated by the host galaxy. Several classification diagrams have been developed to determine the AGN contribution to an observed spectrum based on certain spectral features, such as high ionisation emission lines like Ne V , [Ne II] and O IV, the EW of PAH features and the strength of the silicate feature at 9.7 μm. A number of techniques have also been developed to model the observed MIR spectra and constrain the AGN and starburst contributions (see e.g. Schweitzer et al., 2008; Nardini et al., 2008; Deo et al., 2009; Feltre et al., 2013).

Polycyclic Aromatic Hydrocarbons: Polycyclic Aromatic Hydrocarbons (PAHs) are abundant, ubiquitous, and a dominant force in the interstellar medium of galaxies (see e.g., for a review). Aromatic features are already a significant component of dusty galaxy spectra as early as $z \approx 2$ (Yan et al., 2005, ApJ, 628, 604). and the infrared (IR) emission features at 3.3, 6.2, 7.7, 8.6, and 11.3 μm are generally attributed to IR fluorescence from (mainly) far-ultraviolet (FUV) pumped large polycyclic aromatic hydrocarbon (PAH) molecules. As such, these features trace the FUV stellar flux and are thus a measure of star formation. The interstellar IR emission spectrum is incredibly rich and shows a wealth of detail. It is dominated by major emission features at 3.3, 6.2, 7.7, 8.6, 11.2, 12.7, and 16.4 μm. In addition, there are weaker features at 3.4, 3.5, 5.25, 5.75, 6.0, 6.9 and 7.5μm. Given the redshift of our ERQs and the MIRI wavelength coverage we will coverage $1.36 \leq \lambda_{\rm emitted} \leq 8.6\mu$m.

The mid-IR spectral region also presents a suite of high-ionization lines: [S IX] at 1.252μm, [Si X] at 1.430μm, [Si XI] at 1.932μm, [Si VI] at 1.962μm, [Ca VIII] at 2.321μm, [Si VI] at

2.483μm [Si IX] at 3.935μm and [Ar II] at 6.97μm. However, most critically, we have access to the [Ne VI] line at 7.65μm, which with an Ionization potential of 158 eV is much too high for stars. Critical density of 106 cm-3 and very low interstellar extinction Ratio to hydrogen recombination lines virtually independent of ionization parameter **The [Ne VI] 7.65 mm line can be used to measure the instantaneous luminosity of the central engine.** Not readily confused with high mass X-ray binaries The calibration should remain valid over the expected range of metallicity.

With the IFU spatial information, at medium resolution, we will be able to (i) map the PAH emission structure of the extremely red quasars and (ii) look for offsets in these emissions that could well be indicative of 'AGN feedback.

Integral Field Unit Observations. The ability for the MRS to obtain integral field unit spectroscopy allows us to investigate the *spatial information* associated with the high IR fluxes in the ERQs. The spatial distribution of the IR will give direct clues to the power source of the IR emission. The IFU aspect of the Medium Resolution Spectrometer will allow unprecendet detailed investigations of the both the central AGN IR emission and any potentially extended emission in $z \approx 2.5$ quasars. As a null hyopthesis, we suggest that weak PAH emission will be in the nuclear regions and strong(er) PAH emission in the extended source. However, very recent studies with Hα in of$z \sim 2$ quasars suggest that narrow Hα emission might be from a spatially unresolved source.

Our final primary science goal will be to examine the IR spectral emission lines (PAH or high ionization) and place them in context with the host galaxy by looking for emisson line offsets or extreme blends. The kinematics of the [O III] $\lambda\lambda$4959,5007 Å emission lines are *known to extreme* in these objects, being very broad (FWHM=2600-5000 km s^{-1}) and strongly blueshifted (by up to 1500 km s^{-1}; Figure 2, *right*). We also know that the [O III] kinematics are positively correlated with infrared luminosity. Can we place the PAH and AGN emission in the same consistent kinematic structure? Is there a spatial variaion of the kinematics of the IR emission lines, and if so, is it consistent with a strong 'AGN feedback' phase?

Bibliography

Armus et al., 2007; • Fabian, 2012, ARAA 50, 455 • Hernan-Caballero & Hatziminaoglou, 2011 • Kormendy & Ho, 2013, ARAA, 51, 511 • Heckman & Best, 2014, ARAA, 52, 589 • Mampaso, Prieto &Snchez, Infrared Astronomy, 2004, ISBN 9780521548106 • Peeters et al, 2004, ApJ, 613, 986 • Spoon et al., 2007; • Tielens, 2008, ARAA, 46, 289 • Veilleux et al., 2009;• Yuan & Narayan, 2014, ARAA, 52, 529 • Zakamska, 2016, MNRAS, 459, 3144 •

Technical Description

Overall Experimental Design: We have honed in on a specific early release science case that will engage a broad cross-section of the astronomical community, and deliver a dataset for MIRI MRS that can be used for e.g. extragalactic galaxy and AGN studies in Cycle 2. After discussion with the MIRI Team (A. Glasse; priv. comm.), we settled on the ideology of picking out one instrument (MIRI) and one observing mode (MRS) and making sure we deliver the highest quality data analysis and SEPs here for the community. Observations with MIRI MRS will also directly answer the science questions we have posed.

MIRI MRS is the instrument of choice since no other medium resolution spectrometer on JWST observes longward of 5μm; going redder than this is crucial in order to detect PAH features in $z > 2$ objects. *Due to the nature of the ERS program, we note that we do not necessarily have to observe a full, representative sample, and given the quanity of Discretionary time available for the ERS, a natural program size* $\lesssim$*30-40 hours.* Moreover, our program speficially tests only a particular mode of MIRI, alebit in detail, and thus our time request is curtailed in that manner. With these considerations in place, and with the desire to immediately gain high signal-to-noise spectra in order to investigate the physics and chemistry of quasar PAHs, along with observational overhead concerns, pushes us to observe four quasars, each object for 3.6 hours, for a total program Charged Time of 22.20 hours.

Short term goals: Observe do the scinece here. Longet term goals: representative sample, range of redshifts especially to cover the e.g. 9.7um silicate feature, accessible for MIRI for $z \lesssim 2$ objects[2]

MIRI MRS Observing Overview

We will be utiliSsing the medium-resolution integral field unit (IFU) and spectroscopy mode. For our MRS operations we: shall operate over the full wavelength range; employ the 4-point dithering pattern, optimized for point sources and using the SLOW detector read-out mode. For the observations themselves, a wide range of considerations (sample size, desired very high SNR, time available for ERS programs, level of read noise etc.) we converge on: 15 Groups 3 Integrations and 1 Exposures for a total of 12,912 seconds science exposure per object. *Using Smart Accounting, the total Charged Time is 22.20 hours.*

MIRI Observing Details

Our observational set-up is:

- MIRI MRS.
- Full spectral coverage; thus we will use all three different spectral settings, SHORT (A), MEDIUM (B), and LONG (C).
- Since with the ERQs we are likely to be observing either point sources or compact sources, we choose to use the point source optimized, "4-point ALL" dither pattern.

[2]Our core ERQ sample currently has $2.0 \leq z \leq 3.4$, but as noted in Hamann et al. (2017) this is due to the SDSS/BOSS optical survey selection and is not an intrinstic property per se.

Object Name (SDSS)	J0834+0159	J1232+0912	J2215-0056	J2323-0100
Object R.A.	08:34:48.48	12:32:41.73	22:15:24.00	23:23:26.17
object declination	+01:59:21.1	+09:12:09.3	−00:56:43.8	−01:00:33.1
r-band AB magnitude	21.19±0.05	21.11± 0.05	22.27±0.12	21.62± 0.08
WISE W4-band Vega magnitude	6.88±0.09	6.78 ±0.09	7.91±0.24	7.76±0.22
WISE W4-band flux, F_ν	14.80 mJy	16.23 mJy	5.73 mJy	6.58 mJy
$i_{\rm AB} - W3_{\rm AB}$	6.0	6.8	6.2	7.2
Redshift z	2.591	2.381	2.509	2.356
REW C IV	209±6	225±3	153±5	256±5
C IVFWHM km s^{-1}	2863±65	4787±52	4280±112	3989±62
[O III] FWHM erg s^{-1}	2811	4971	3057	2625
ALMA Band 6	*pending*	√	*pending*	√
HST Cycle 24 ACS+WFC3	obtained	*pending*	*pending*	*pending*
Spectro-polarimertry	×	√	√	×
JWST target visibility (Start)	2019-04-01	2019-05-08	2019-05-22	2019-06-07
JWST target visibility (End)	2019-05-07	2019-07-01	2019-07-15	2019-07-29

Table 1: Our four Extremely Red Quasar targets. All four quasars were first identifired in Ross et al. (2015). Values of e.g. REWs, FWHMs are from Zakamska et al. (2016) and Hamann et al. (2017).

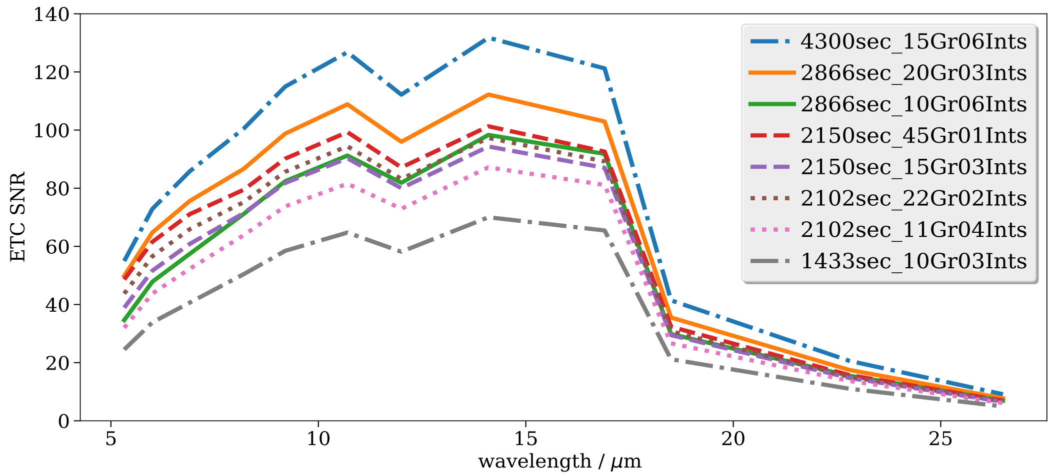

Figure 3: ETC calculations of MIRI SNR values for a range of NGroup sizes, Integrations and the associated Science exposure time (per Wavelength disperser).

dither). This is the only MIRI MRS dither patterns that guarantees "GOOD" (i.e. half-integer) sampling throughout the common field of view across all four channels.

- We are interested in only a single object per point, so no mosaicking is necessary.
- MIRI Detector Readout mode:: SLOW JWST MIRI's "Slow mode" readout pattern offers fewer detector artifacts and slightly lower detector noise than the "fast mode", making it a good choice for faint source medium-resolution spectroscopy where the sky backgrounds are very low. This is exactly what we want for our ERQ observations.
- Subarray is FULL. This is fixed for MRS.

We take the "core ERQ" SED that is given in Hamann et al. (2017) and is fully representative of the ERQ population at large. The file (found on the GitHub) of `core_ERQ_SED_notLog.dat` is used here. We normalize this SED at a wavelength of 23μm to a source flux density of 5mJy, again very representative of the WISE W3/4-detected ERQ population given in Ross et al and Hamann et al.

At this stage we *do not* include any emission (or absorption) lines since... In the ETC we assume the Shape of the source is Point. Other notes, using the ETC, include having: Medium Backgrounds; 'IFU Nod In Scene'; Aperture location Centered on source; Aperture radius of 0.3"; Nod position in scene of $X = Y = 0.5''$. Our JWST ETC Workbook has `wb ID 7474`.

APT, Overheads and Smart Accounting.

All the above details in are out APT. Visit Planner was loaded and Smart Accounting run. Our full proposal comes in at 22.20 hours of charged time.

Object name, SDSS J	R.A. (J2000)	Decl (J2000)
J000610.67+121501.2	00:06:10.6778	+12:15:01.274
J014111.13-031852.5	01:41:11.1369	-03:18:52.567
J083200.20+161500.3	08:32:00.2000	+16:15:00.300
J113721.46+142728.8	11:37:21.4663	+14:27:28.879
J121704.70+023417.1	12:17:04.7013	+02:34:17.151
J134254.45+093059.3	13:42:54.4591	+09:30:59.396
J135608.32+073017.2	13:56:08.3200	+07:30:17.200
J162518.66+144509.9	16:25:18.6600	+14:45:09.900
J215855.10-014717.9	21:58:55.1028	-01:47:17.973
J222307.12+085701.7	22:23:07.1253	+08:57:01.735

Table 2: A list of Secondary targets. All of these objects will have ALMA Cycle 5 Band 6 observations. Observations of these would allow us to achieve our SEP and Science goals.

Plan for Alternative Targets

We have 14 ERQs that will be observed with ALMA Cycle 5, Band 6, four of which are our primary targets. The remaining 10 objects are given here as alternative targets. The redshifts and e.g. WISE W3/W4-band magnitudes and fluxes are come from the same distribution as for the core targets, hence there is no need to change the observational strategy.

Special Requirements

There are no Special Observational Requirements for our ERS.

Justify Coordinated Parallel Observations

We are not inducing Coordinated Parallels observations.

Justify Duplications

There are no duplicated observations.

Data Processing & Analysis Plan

Summary of DD-ERS Data Products

Our primary SEP task and goal is to produce a Python package that quickly manipulates and analyzes the full MRS Level 3 data, in particular the MRS Spectral Cubes and 1D spectra.

We will take the output from the third stage of the pipeline for MRS spectroscopy, the CALIFU3 level data and analyse this. We note there is already Python legacy code for this type of analysis: ttps://spectral-cube.readthedocs.io/`spectral-cube.readthedocs.io`.

NOTE TO NPR, THIS NEEDS UPDATED!! Further items that we will deliver include:

- Participation in community briefings organized by STScI; written/oral updates on progress; written/oral documentation of lessons-learned.
- Software with documentation data analysis and modeling enhanced data processing
- Enhanced data products with documentation aligned multiband images, extracted spectra, etc catalogs

General Outline and Motvations Driving Data Processing & Analysis

We are already ensuring open access to representative data sets, processeing pipelines and analysis tools in support of the preparation of both Cycle 1 and Cycle 2 proposals. The key links are::

`github.com/d80b2t/JWST_ERS`
(the P.I.'s personal and public GitHub repository).

`github.com/miri-mrs`
(a "Organizational" public GitHub repository for the Community).

`miri-mrs.readthedocs.io`
(With the source code here: `https://github.com/miri-mrs/ERQs/tree/master/docs`).

MIRISim

MIRI data simulations (at ESA) include an Integral Field observation with the Medium Resolution Spectrograph (MRS), a Low Resolution Spectrograph (LRS) observation, and an imaging observation. (Credit: ESA, Pamela Klaassen and the MIRISim Team). **MIRISim does not produce final, calibrated data. MIRISim produces stuff that looks like it has come off of MIRI.**

Delivery Schedule for Science-Enabling Products.

Our ERQ ERS proposal is the first part of a multi-cycle proposal project and plan. As such, we are *already highly motivated to produce the data processing tools, codes, documentation* *and identify the critical science-enabling products well in advance of the release of the Cycle 2 Call for Proposals (September 2019).* Our major milestones are laid out here::

Proposed Delivery for SEPs

Before Cycle 1 GO Proposal Deadline (end Feb 2018): Delivery of the first set (beta) of MIRI MRS SEPs before the Cycle 1 GO Deadline (March 2018). Proin non tempus velit. Etiam laoreet, enim nec scelerisque dictum, tortor massa tempor enim, id pretium justo quam ac lectus. Maecenas diam nibh, interdum at lobortis sit amet, dignissim et quam.

Prior to Launch (March 2018 - October 2018): The release of our v1.0.0, with MIRSim mock data. Sed tincidunt faucibus risus, congue tempus nisl consectetur eget. Suspendisse venenatis turpis ut risus aliquam interdum. In at velit sed ligula dictum dignissim ut et dui. Curabitur ac scelerisque purus.

Commissioning (November 2018-April 2019): Ramp-up of the Postdoctoral Fellows. Donec elit tortor, scelerisque ac molestie id, hendrerit sit amet ipsum. Maecenas non tempus sem. Pellentesque ut enim velit, eu sagittis elit. Nulla in elementum erat.

ERS and Cycle 1 (April 2019-September 2019): Rapid version updates once the start of science operations commences in April 2019. In dictum arcu at nisi porttitor commodo. Donec felis felis, elementum sit amet ultrices ac, interdum nec ante. Nullam eget faucibus lectus. Donec vitae eros sapien, et faucibus ligula. Aenean pharetra viverra fermentum.

After Cycle 2 GO Deadline (post-September 2019): Continue to provide regular (every 6 months) major version update. Nullam eget faucibus lectus. Donec vitae eros sapien, et faucibus ligula. Aenean pharetra viverra fermentum.

Co-Investigators and Delivery of Science-Enabling Products.

Everyone named on this proposal is part of the "core team". A bibliography and SEP tasks of our team can be found here and the SEP Deliverables are `here`.