Rationale for DD-ERS Program

With our ERS MIRI observations of bright WISE W4 quasars, we will deliver all the tools necessary to the community in order to optimize Cycle 2 proposals of 5-30μm milliJansky bright sources. This is *a fundamental tool* for the exploitation of a key MIRI instrument mode

We will satisfy the Goals and Principles of the DD ERS program by:

- 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.

These goals distinguish the DD ERS program from standard GO investigations. In service of these goals, DD ERS proposals are invited from the community. The DD ERS program is guided by the following key principles:

- Projects must be substantive science demonstration programs that utilize key instrument modes to provide representative scientific datasets of broad interest to researchers in major astrophysical sub-disciplines. Note that a meritorious DD ERS project need not cover every mode of the observatory. The request should match the focused science goals of the proposal.
- Projects must design, create, and deliver science-enabling products to help the community understand JWST's capabilities. An initial set of products must be delivered by the release of the Cycle 2 GO Call for Proposals (September 2019). Each project must define a core team to be responsible for the timely delivery of such products according to a proposed project management plan, with performance subject to periodic review.
- All observations must be schedulable within the first 5 months of Cycle 1 (planned to be from April to August 2019), and a substantive subset of the observations must be schedulable within the first three months. Target lists must be flexible to accommodate possible changes to the scheduled start of science observations.
- Both raw and pipeline-processed data will enter the public domain immediately after processing and validation at STScI. These data will have no exclusive access periods (i.e., no proprietary time).

STScI recognizes and supports the benefits of having diverse and inclusive scientific teams involved in the formulation of ERS proposals. Programs with diverse representation of community members in a given sub-discipline helps ensure that the investigations will be of broad interest. Broad involvement also facilitates the dissemination of JWST expertise through a more extensive network, and promotes more equitable participation in JWST scientific discovery.

The DD ERS program will be essential for informing the scientific and technical preparation of Cycle 2 General Observer (GO) proposals, submitted seven months after the end of commissioning.

Critically, we have alreayd 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 Imager and MRS.

Relation to Spitzer IRS:

Major Achievement of Spitzer was IRS.
However IRS had fringing.
Also, Spitzer IRS died before WISE; therefore now WISE W4 objects were observed by the IRS.

■ Scientific Justification

One lasting scientific legacy of the *Hubble Space Telescope (HST)* will be the discovery of giant black holes at the centers 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 correlation between black hole mass and galaxy properties. 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), this is one of the outstanding questions in astrophysics.*

Furthermore, discovery of spectral lines in active galaxies reveals that black holes can trigger massive star formation.

As such, the two main energy sources available to a galaxy are nuclear fusion in stars and gravitational accretion onto compact objects. The link between massive galaxies and the central super-massive black holes (SMBHs) that seem ubiquitous in them is now thought to be vital to the understanding of galaxy formation and evolution ([1], [2]). As such, huge observational and theoretical effort has been invested in trying to measure and understand the physics involved in these enigmatic systems.

Hubble discovered $M - \sigma$.
Gives rise to the idea of AGN/QSO feedback (in order to shape the LF at the high-mass end)
However, *direct observational evidence* for AGN feedback is conspicuous by its absence. This 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 suggest we are seeing 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 milliJansky luminous AGN *are ideal targets for JWST MIRI.*

The Extremely Red Quasar Population: Matching the quasar catalogues of the Sloan Digital Sky Survey (SDSS), 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 colours. These quasars have extremely high infrared-to-optical ratios, $r_{\rm AB} - W4_{\rm Vega} > 14$ mag, i.e., $F_\nu(22\mu{\rm m})/F_\nu(r) \gtrsim 1000$.

Hamann et al. (2017) then fully and properly refined the selection of ERQs, changed the definition based on other data and common properties, and indeed found many more objects in this new scheme. Red quasars are candidate young objects in an early transition stage of massive galaxy evolution. Our team recently discovered a population of extremely red quasars (ERQs) in the Baryon Oscillation Spectroscopic Survey (BOSS) that has 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. Here we present a new catalog of C iv and N v emission-line data for 216,188 BOSS quasars to characterize the ERQ line properties further. We show that they depend sharply on UV-to-mid-IR color, secondarily on REW(C iv), and not at all on luminosity or the Baldwin Effect. We identify 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. A broader search finds 235 more red quasars with similar unusual characteristics. The core ERQs have median luminosity $\langle \log L(\mathrm{ergs/s}) \rangle \sim 47.1$, 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 and line properties are inconsistent with normal quasars behind a dust reddening screen. We argue that the core ERQs are a unique obscured quasar population with extreme physical conditions related to powerful outflows across the line-forming regions. Patchy obscuration by small dusty clouds could produce the observed UV extinctions without substantial UV reddening. Red quasars are candidate young objects in an early transition stage of massive galaxy evo- lution. Our team recently discovered a population of extremely red quasars (ERQs) in the Baryon Oscillation Spectroscopic Survey (BOSS) that has a suite of peculiar emission-line properties including large rest equivalent widths (REWs), unusual wingless line profiles, large N V/Ly, N V/C IV, Si IV/C IV and other flux ratios, and very broad and blueshifted [O III] 5007. Here we present a new catalogue of C IV and N V emission-line data for 216 188 BOSS quasars to characterize the ERQ line properties further. We show that they depend sharply on UV-to-mid-IR colour, secondarily on REW(C IV), and not at all on luminosity or the Baldwin Effect. We identify a core sample of 97 ERQs with nearly uniform peculiar properties se- lected via iW3 4.6 (AB) and REW(C IV) 100 A at redshifts 2.03.4. A broader search finds 235 more red quasars with similar unusual characteristics. The core ERQs have median luminosity log L(ergs s1) 47.1, sky density 0.010 deg2, surprisingly flat/blue UV spec- tra given their red UV-to-mid-IR colours, and common outflow signatures including BALs or BAL-like features and large C IV emission-line blueshifts. Their SEDs and line properties are inconsistent with normal quasars behind a dust reddening screen. We argue that the core ERQs are a unique obscured quasar population with extreme physical conditions related to powerful outflows across the line-forming regions. Patchy obscuration by small dusty clouds could produce the observed UV extinctions without substantial UV reddening.

Zakamska et al. (2016) used XShooter on the Very Large Telescope to measure rest-frame optical spectra of four $z \sim 2.5$ extremely red quasars with infrared luminosities $\sim 10^{47}$ erg s^{-1}. We present the discovery of very broad (full width at half max$= 2600 - 5000$ km s^{-1}), strongly blue-shifted (by up to 1500 km s^{-1}) O IIIλ5007Å emission lines in these objects. In a large sample of type 2 and red quasars, O IIIkinematics are positively correlated with infrared luminosity, and the four objects in our sample are on the extreme end both in O IIIkinematics and infrared luminosity. *As such, 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 IIIemission might be extended on a few kpc scales, which would suggest that the extreme outflow is affecting the entire host galaxy of the quasar. These sources may be 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.*

Alexandroff et al. (2017 submitted and in prep.)....

Next Steps:

I think the easiest useful thing we could get from NIR spectra is a test for any PAH emission at all. The mid-IR emission is booming in the ERQs. The PAHs would show that it's dominated by star formation. But my guess is that its dominated by hot dust in the torus, so no PAHs. Its an interesting test either way, but to make it more appealing we should think about other lines available in the MIR. I dont know anything about JWST capabilities, but if we can search for some forbidden lines used in local ULIRG/AGN studies, we could say a lot more about the kinematics and what powers the lines. This paper by Veilleux seems like a good guide for lines that might be available: https://arxiv.org/abs/astro-ph/0201118

Relation to Spitzer IRS: Major Achievement of Spitzer was IRS.
$R \sim 600$, now $R \sim 2000s$, which allows *chemistry.*
Spitzer IRS died before WISE; therefore now WISE W4 objects were observed by the IRS.
i.e. no $z \sim 2.5$ ERQs w/ feedback in action were observed.

MIRI Imaging: Imaging of the ERQs will tell us what environments they live in (currently totally unknown).
Just look at the ERQs: flux from central source $\Rightarrow$ AGN; flux from extended $\Rightarrow$ SF; Big puzzle since Spitzer (e.g. and cf. the submm population).

Description of the Observations

Describe the targets and observational modes to be used. Quantitative estimates must be provided of the accuracy required to achieve key science goals. Proposers must demonstrate that all observations can execute in the first 5 months of Cycle 1 (planned to be from April to August 2019), and that a substantive subset of the observations are accessible in the first 3 months. This description should also include the following::

a Plan for Alternative Targets: As described in JWST DD ERS Special Observational Policies, proposers should qualitatively describe the availability of alternate targets and the process used to identify those targets should the start of science observations be delayed. Robust ERS programs involve science investigations that can be performed with a variety of different targets and observations.

b Special Observational Requirements (if any): Justify any special scheduling requirements, e.g., time-critical observations.

c Justification of Coordinated Parallels (if any): Proposals that include coordinated parallel observations should provide a scientific justification for and description of the parallel observations. It should be clearly indicated whether the parallel observations are essential to the interpretation of the primary observations or the science program as a whole, or whether they address partly or completely unrelated issues. The parallel observations are subject to scientific review, and can be rejected even if the primary observations are approved.

d Justification of Duplications (if any): as detailed in the JWST DD ERS Proposal Policies and the JWST Duplicate Observations Policy, observations taken as part of the DD ERS program cannot duplicate those specified for the GTO Cycle 1 Reserved Observation Catalog (planned for release on June 15, 2017). Any duplicate observations must be explicitly justified.

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-b& AB magnitude	21.20±0.05	21.11± 0.05	22.27±0.12	21.62± 0.08
Redshift $z_{\rm in}$	2.591	2.381	2.509	2.356

■ Plan for Alternative Targets

■ Special Requirements

■ Justify Coordinated Parallel Observations

■ Justify Duplications

Data Processing & Analysis Plan

Dave Bowman: Hello, HAL. Do you read me, HAL? HAL: Affirmative, Dave. I read you. Dave Bowman: Open the pod bay doors, HAL. HAL: I'm sorry, Dave. I'm afraid I can't do that. Dave Bowman: What's the problem? HAL: I think you know what the problem is just as well as I do. Dave Bowman: What are you talking about, HAL? HAL: This mission is too important for me to allow you to jeopardize it. Dave Bowman: I don't know what you're talking about, HAL. HAL: I know that you and Frank were planning to disconnect me, and I'm afraid that's something I cannot allow to happen. Dave Bowman: [feigning ignorance] Where the hell did you get that idea, HAL? HAL: Dave, although you took very thorough precautions in the pod against my hearing you, I could see your lips move. Dave Bowman: Alright, HAL. I'll go in through the emergency airlock. HAL: Without your space helmet, Dave? You're going to find that rather difficult. Dave Bowman: HAL, I won't argue with you anymore! Open the doors! HAL: Dave, this conversation can serve no purpose anymore. Goodbye.