Revolutionary Quasar Science with *James Webb Space Telescope* Observations: Notice of Intent for a Director's Discretionary Early Release Science Program

The James Webb Space Telescope will revolutionize our understanding of the quasar phenomenon.

Overview

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. As such, huge observational and theoretical effort has been invested in trying to measure and understand the physics involved in these enigmatic systems.

In this *Notice of Intent* (NoI), we outline six particular science cases that focus on the role of accreting supermassive black holes and active galactic nuclei central engines, and their direct consequences to galaxy formation and evolution at Cosmic Dawn ($z > 6$) and Cosmic Noon ($z \sim 2-5$).

The key science goals for the DD ERS Program, are:

- Active Black Holes in very high-z galaxies.
- Evidence for the Transition Mass that quenches AGN activity;
- What triggers luminous QSO acticity at Cosmic Noon?
- Extremely Red Quasars;
- Changing Look Quasars;
- True Type 2 QSOs are high redshift.

Science Case

I. Active Black Holes in very high-z galaxies. JWST plans to image and obtain spectra of very high-z, $z \gtrsim 12$ galaxies in legacy extragalactic deep fields (e.g. GOODS-N (Hubble Deep Field North), GOODSS (Ultra Deep Field), Extended Groth Strip (EGS), UKIDSS Ultra-Deep Survey (UDS) and COSMOS. Discovery, and then population studies of the active AGN in the galaxies present in the deep fields. Although AGN are not suspected to be the main contributors to Reionization, this still needs to be conclusively ruled out.

II. Evidence for the Transition Mass that quenches AGN activity. Recent high-resolution hydrodynamic simluations, e.g. the EAGLE simulation, (Bower et al. 2017) suggest thar the Red Sequence and Blue Cloud of galaxies is a consequence of the competition between star formation-driven outflows and gas accretion on to the supermassive black hole at the galaxys centre. Moreover, at a stellar mass of $\sim 3{\times}10^{10}$ $M_{\odot}$ and a halo mass of 10^{12} $M_{\odot}$, the outflow ceases to be buoyant and star formation is unable to prevent the build-up of gas in the central regions. This triggers a strongly non-linear response from the black hole. Its accretion rate rises rapidly, heating the galaxys corona, disrupting the incoming supply of cool gas and starving the galaxy of the fuel for star formation.

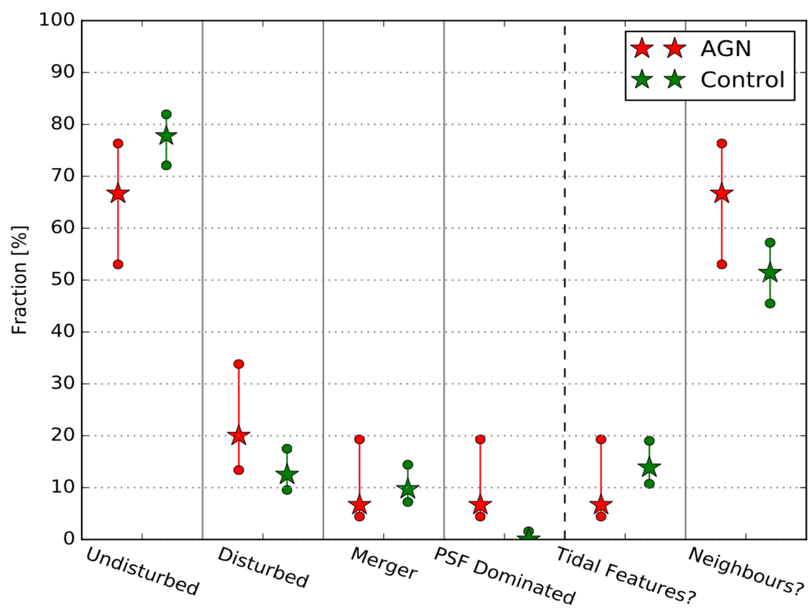

Figure 1: Villforth et al, arXiv:1611.06236v2; their Figure 4. Visual classification of all resolved AGN host galaxies and matched control galaxies. AGN are shown in red, control sample in green. The error bars show 1 confidence intervals calculated following Cameron (2011).

III. What triggers luminous QSO acticity at Cosmic Noon? Traditional thinking has long suggested that galaxy major mergers are responsible for luminous QSO activity. However, at the heigh of the quasar epoch, $z \sim 2-4$, a.k.a. "Cosmic Noon", there is incredibly scant observational evidence that the majority of the black hole mass build up at the knee of the quasar luminosity function was trigger by a major merger process.

JWST will directly answer this outstanding question.

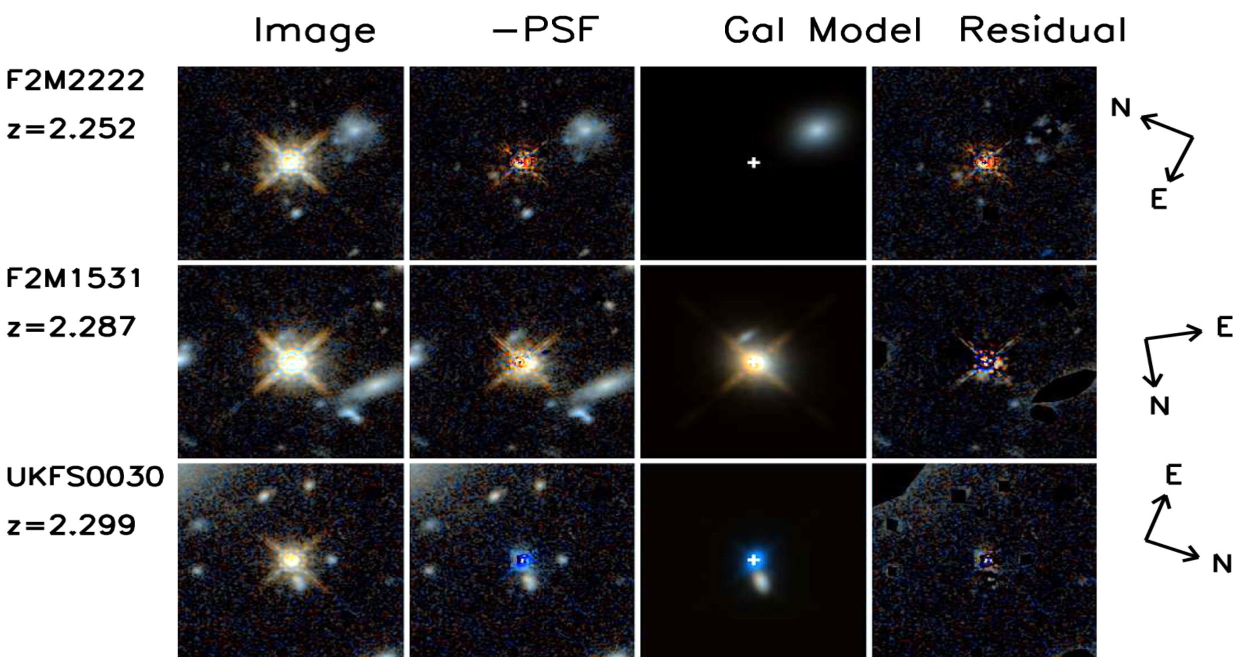

Figure 2: *From: Glikman et al., 2015, ApJ, 806, 218; their Figure 5.* Two color HST images of the eight lower-redshift quasars studied in this paper imaged with F105W and F160W. Each row represents a separate object. The first column is the original image shown at a scale of 8 8. The second column shows the residual image after subtracting only the point-source component. The third column shows the model for all but the point-source component; the blank frame is a source to which no host component could be fit. The final panel shows the full residual including masked regions and is indicative of the overall goodness of fit. Evidence of mergers and disrupted host galaxies is seen in most the sources. We apply the redgreenblue color-combining algorithm of Lupton et al. (2004) to our images, and we average the count rate from the F105W and F160W images to produce the green frame.

IV. Extremely Red Quasars The discovery of extremely red QSOs (ERQs) with $r - [22] > 14$ colours from the WISE All-Sky Survey and spectroscopy from SDSS and BOSS, seems to provide a key observational clue to the "major merger" evolutionary theory for QSO activity. However, the large fraction of AGN which remain heavily obscured will need mid-infrared spectroscopy in order to understand the role this optically hidden population play in the evolution of galaxies and the integrated light of the Universe. Given the fellowship timescale, this makes a natural bridge to the *James Webb Space Telescope* and observations with the MIRI spectrograph.

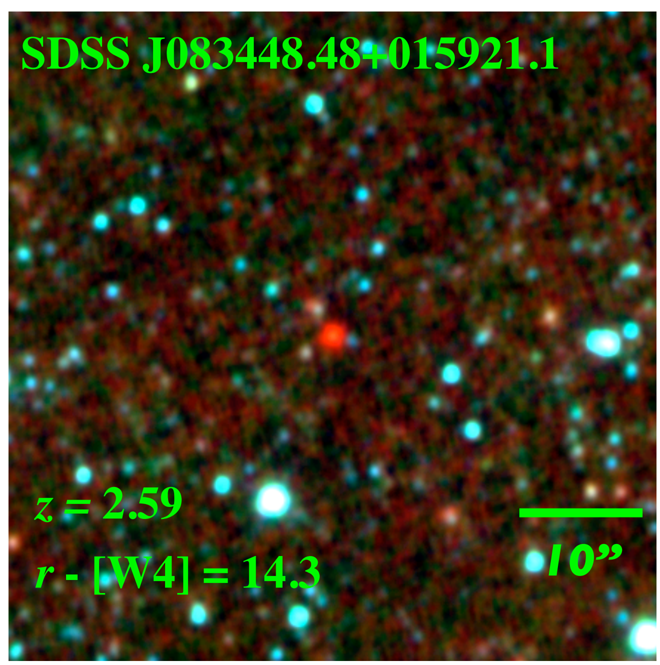

Figure 3: A WISE 3.4, 4.6 and 12μm image of a $z = 2.59$ extremely red quasar, selected on its $r - [22]$ colour, discovered by [24]. This object has a 22μm flux indicative of $L_{IR} \gtrsim 10^{14} L_{\odot}$, and one interpretation could be we are witnessing the "birth" of an unobscured quasar.

V. Changing Look Quasars Recently "Changing-look" quasars (CLQs; [18-21]), have been identified, and are defined to be luminous AGN which are observed to have a dramatic appearance or disappearance of their broad emission-line (BEL) component. CLQs are extremely important since they offer a direct observational probe into the physical processes dictating the structure of the AGN broad-line region (BLR), *and doing so on observed-frame year-*

timescales. The timescales that are measured for CLQs can potentially be associated with the viscous timescale (associated with the drift time through the accretion disk), the light crossing timescale (critical for reverberation mapping and disk reprocessing) and the dynamical timescale of the BLR. *CLQs are thus an ideal laboratory for studying accretion physics, as the entire system responds to a large change in ionising flux on a human timescale.*

VI. True Type 2 QSOs are high redshift. 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. 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.

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1 Science Case

Relevance to DD ERS. Survey Description.

Observation Modes.
In particular, and noting the PIs host institution, we aim to test multiple modes of the JWST MIRI including imaging, low-resolution slitted and slitless spectroscopy, medium-resolution integral field unit (IFU) spectroscopy and coronagraphy.

Source of Targets.
(i): The traditional Extragalactic Deep Fields; *(ii):* an

Mid-IR properties of QSOs and JWST.

References

[1]Fabian, 2012, ARAA, 50, 455
[2]Alexander et al., 2012, NewAR, 56, 93
[3]Schneider et al. 2010, AJ, 139, 2360
[4]Pâris et al., 2012, A&A, 548, A66
[5]Dawson et al. 2013, AJ, 145, 10
[6]Ross et al., 2012, ApJS, 199, 3