ERC-2018-CoG

Data Science at the Edge of the Universe: Using Quasars to kickstart the new field of Extragalactic Time-Domain Astrophysics

Principle Investigator: Nicholas P. Ross
Host Institution: University of Edinburgh
Duration: 60 months

Black holes are intriguing objects. These regions of the Universe where mass is so dense, and gravity so strong, that even light cannot escape, were once thought mere oddities due to their extreme properties. Today, however, black holes are now thought to be vital in the formation and lives of galaxies, including our own Milky Way. Why are there a billion solar mass black holes at the centres of large galaxies? How did they form and how do they grow? Do they have any influence on the galaxy itself? And, are the fate of the galaxy and black hole intertwined? These are the key questions in contemporary astrophysics and the issues this research project will answer.

Data science, is a new interdisciplinary field of scientific methods and computational techniques that extracts knowledge and insights from data in various forms and often large volumes. It employs methods and theories drawn from many fields including mathematics, statistics, and computer science, in particular from the subdomains of machine learning, classification, databases, and visualization. As such, modern observational astrophysics must be considered a ``data science”.

Here we propose to kickstart the new field of Extragalactic Time-Domain Astrophysics by building on the P.I.’s data science experience and by using novel observational techniques to study accreting black holes in the early Universe. We will do this by utilizing and combining the firehose of data from several new large surveys that start to come online from late 2019 onwards. The unique aspect of this proposal is to breakdown the data silos of these new surveys. In doing so, we will learn about one of the two fundamental energy sources available to galaxies (accretion onto the central supermassive black hole) and perform the observational tests to gather the evidence to distinguish between galaxy evolution models and theory. We will also be best positioned to discover totally new extragalactic phenomena.

a. Extended Synopsis

Overview and Objectives

Current theories of galaxy formation and evolution strongly suggest that central, supermassive black holes (SMBHs) have a profound effect on the galaxies that they live in [Vogelsberger et al., 2014, Schaye et al., 2015, Somerville and Davé, 2015, Davé et al., 2017]. This is not surprising since the potential energy associated with mass accretion onto a supermassive black hole is comparable to that generated via the nuclear fusion in the galaxy's stars [see e.g. Fabian, 2012]. Thus when a galaxy goes through a "quasar" phase (where gas is supplied and accreted by the SMBH) there is ample energy to potentially impact the host galaxy and the surrounding intergalactic medium.

However, the details of the physical processes involved in how this energy escapes the inner most regions of the galaxy and then interacts with the gas, dust, stars and dark matter, is currently poorly understood, with current observational data giving more puzzles than clues on how to make progress. Significant further issues arise since startling new observations by the P.I.'s (Nicholas P. Ross; NPR) research team [MacLeod et al., 2016, Ross et al., 2018] show that *quasars vary significantly on timescales of weeks to months*, whereas the accretion disks (that supply 'fuel' for the quasar) should take thousands of years to change their optical emission [see e.g. Lawrence, 2018]. Thus, it is unclear to what level we have an understanding of a physical phenomena prevalent in many astrophysical systems: the accretion disk.

The field of observational extragalactic astrophysics is poised for a fundamental and rapid change. Starting in late 2019, a fleet of new telescopes, instruments and missions will be commissioned, start data taking, and will leap-frog the quality and quantity of data we have available today. These surveys and missions include: the fifth incarnation of the Sloan Digital Sky Survey (SDSS-V[1]); the Large Synoptic Survey Telescope (LSST[2]); the Dark Energy Spectroscopic Instrument (DESI[3]) survey; the 4-metre Multi-Object Spectroscopic Telescope (4MOST[4]) survey, and the ESA *Euclid* mission[5]. Even more imminent is the launch of the *James Webb Space Telescope* (JWST[6]).

This proposal has two broad and well-posed goals. First, we aim to elucidate in detail **how the energy directly associated with a supermassive black holes impacts the universal galaxy population.** We will gain a deep understanding into the physical mechanisms related to central engine black holes; their accretion disk physics, their dynamics on both human and galactic timescales and the role they might play in forming and regulating the galaxy population. Second, we anticipate **the discovery of brand new extragalactic phenomena.** By tapping into the massive and raw discovery space that the new experiments will open up, there is the highly likely outcome of discovering something "brand new" [Ivezic and Tyson, 2008, LSST Science Collaborations et al., 2009]. Our major science objectives are:

1. Characterize the variable extragalactic universe and quasar population.
2. Establish the energy transport mechanisms associated with the"quasar phase", and explain the relation between accretion rate, black hole mass build-up with observed light curve and spectral properties.
3. Develop and link theoretical accretion and galaxy formation models for a fully holistic theory of active galaxies.
4. Discover new extragalactic variable objects.

We will achieve this by leveraging several of the new, large-scale surveys that are coming online in the next few years. These critical observations are made by exploiting the large imaging and spectroscopic datasets that will be available from the SDSS-V, DESI, 4MOST, LSST and ESA *Euclid*. *Crucially, although these projects individually will deliver new state-of-the-art datasets, it is our project that will be the first to break down the associated data silos and combine these data in order to go beyond the state-of-the-art.*

[1] `www.sdss.org/future/` [2] `lsst.org` [3] `desi.lbl.gov` [4] `4most.eu` [5] `sci.esa.int/euclid/` [6] `jwst.stsci.edu`

1. Current State of the Art.

The current state-of-the-art data samples have either $\approx 10^6$ quasars with one spectral epoch, or only a few objects with repeat photometric data, i.e. light-curve information and the accompanying repeat spectra (see Figure 1). NPR has been involved in the production of both of these two types of samples [MacLeod et al., 2016, Pâris et al., 2017]. We plan to collate datasets so that the 10^6 sample have high-fidelity light-curves *and* ample repeat spectroscopy, and in doing so will kick start the new field of Variable Extragalactic Astrophysics.

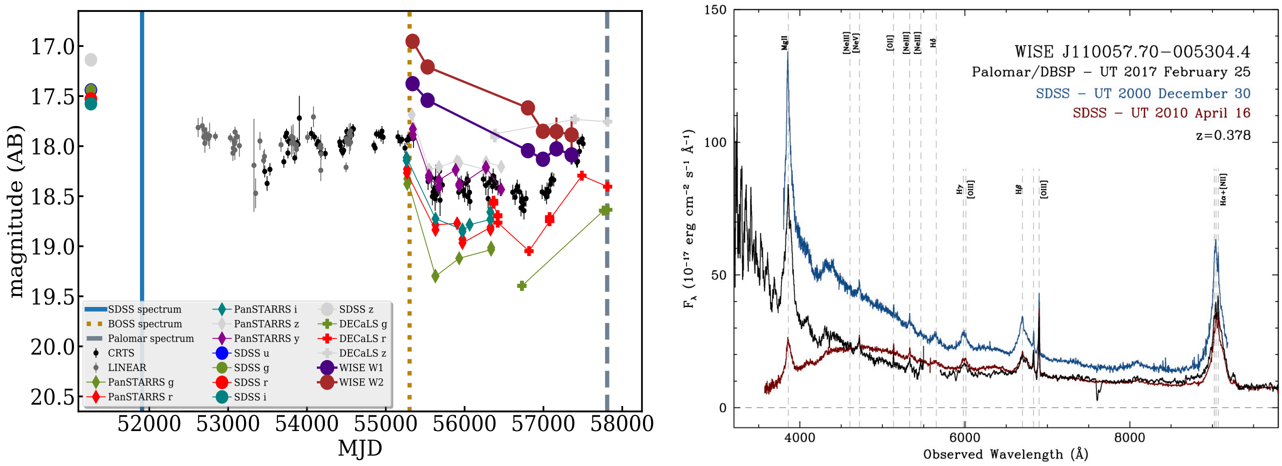

Figure 1: *(Left:)* The optical and infrared light-curve for the redshift $z = 0.378$ quasar J1100-0053 (Ross et al. 2018). Note the fall in the infrared, whereas there is a decrease, but then recovery in the optical. *(Right:)* Three epochs of spectra for J1100-0053. The spectacular downturn in the blue for the 2010 spectrum indicates a dramatic change in the accretion disk.

During its initial phases of operation the Sloan Digital Sky Survey (SDSS) obtained spectra of 1 million galaxies in the local Universe. This dataset has become the *de facto* standard for understanding the present day galaxy population, and sets the boundary conditions for all theoretical comparisons. The paradigm changing success of the SDSS was due to having 1,000,000 objects *with very high signal-to-noise photometry and spectra*, enabling multivariate analysis that is required for galaxy astrophysics investigations. *We desire the sample size and revolutionary understanding with new temporal dimension of the quasar population, as the SDSS had with the low-redshift $z \sim 0.1$ galaxy population.* Our proposal takes quasar astrophysics into the 2020s, going from single objects samples, to surveys and samples of millions of objects, with massive spectroscopic monitoring giving access to the time-domain and leveraging these very large scale next generation missions, telescopes and their datasets.

The timing for this proposal could not be better. The first of the data "firehoses" turns on in late 2019, with the full datastream from our key sources fully online by mid-2022. As such, we have the time to mature our analysis techniques, and then be in the ideal position to take advantage of the initial data releases of all these new projects. Prompt ERC Consolidator level-support is also imperative since final survey design and optimization trade-off studies are being made e.g. for DESI, SDSS-V and LSST over the next ~12-18 months. Having the ability to influence these decisions to our science goals would be very powerful. Also, having the science teams and various collaborations know that the PI is embarking on this program will help attract the best personel for the PDRAs, *who would be guaranteed "First Light" data and science.*

The importance of this branch of astrophysics is already well establish in Europe and is a priority for the next two decades. This is demonstrated by noting that one of the two primary mission goals for the Advanced Telescope for High-ENergy Astrophysics (ATHENA) mission is answering the question "How do black holes grow and shape the Universe?". ATHENA is ESA's second L-class flagship mission, due for launch in 2028.

The scope and remit of an ERC Consolidator grant will allow us to combine these data products in a manner that will not only establish the new state-of-the-art in variable extragalactic astrophysics, but it will also establish and kickstart the new field of variable extragalactic astrophysics itself.

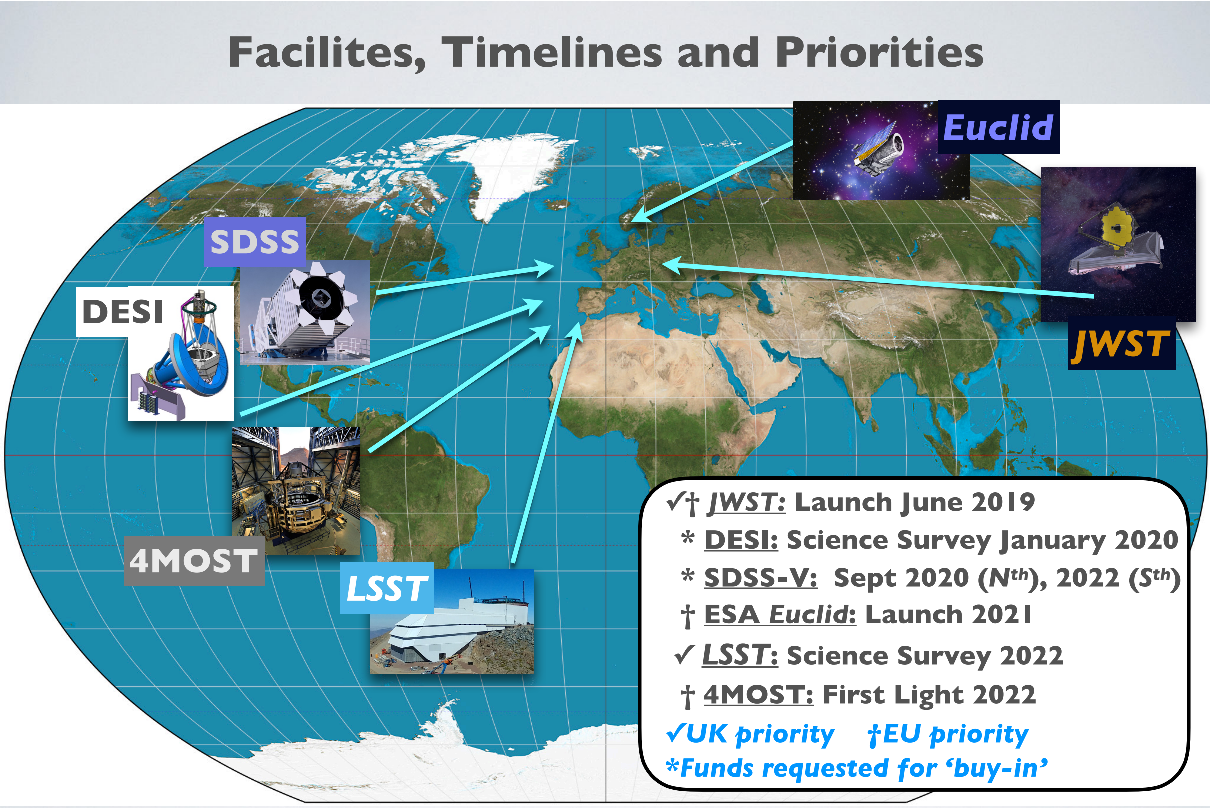

Figure 2: Facilites, Timelines and Priorities. Withe SDSS and DESI in the Northern Hemisphere and 4MOST, LSST in the South, we have full celestial sphere coverage.

2. Methodology

Our proposal contains eight work packages that fall into three broad and complementary categories: observational studies of large numbers (millons) of objects; high-risk, very high-reward observational studies of a small number (10s) of objects; theoretical modeling investigations. Table 1 summarises our overall WP plan. Risks and mitigation strategies are present for each WP as are Key Deliverables.

We define three PDRAs, "PDRA1", "PDRA 2", "PDRA 3" and one PhD student, "PhD1". The skill set of PDRA1 would include development of the underlying tools and techniques necessary to extract meaning from large and/or complex data sets. The skill sets of PDRA2 would include expertise in time series analysis, primarily with optical data but potentially also in other wavebands. The skill set of PDRA3 would include experience with fluid mechanics modelling and/or large computer simulations. PhD1 would have a Masters or a strong 4-year undergraduate degree in Physics or Mathematics with evidence of research-level project work.

WP1: Build an Event Broker: The LSST will deliver three levels of data products and services and being in the U.K. gives us access to all three. In order to utilize the LSST data for our science goals we will need to build an *event broker*, an intermediary program module that interacts with primarily the "Level 3" data products from the LSST. The goal of this WP is to build an Event Broker. **WP1 is low-risk, high-reward.** The heavy-industry computing infrastructure is already being supplied by the LSST Data Access Center and our task will be to build software in a timely and robust manner. With PDRA1 and commitment from the P.I., (NPR) along with the algorithm resources and key personel, e.g. Prof Andy Lawrence (AL) and Prof. Bob Mann (RGM), at the Royal Observatory, Edinburgh, there is no element of this which can be deemed high-risk. **Key Deliverables:** An open-source, well-documented software package that can interact with and return data from the LSST Data Access Center.

WP2: Quasar Catalogue Generation: Building the quasar corpus and cataloguing the observational data will be a large, but vital step in beginning to pursue our science goals. This catalogue will be the glue that binds the observational projects together and will have not only the data, but moreover the metadata to enable the other WPs. The goal of this WP is to construct a quasar catalogue. **WP2 is low-risk, high-reward.** Given the P.I.s (NPR) experience at this specific task, plus the effort level of PDRA2 this WP is low-risk. **Key Deliverables:** An open-source, well-documented science-enabling compendium that will be the state-of-the-art quasar dataset for the 2020s.

WP3: QUASAR DEMOGRAPHIC STUDIES: Following on from the quasar corpus catalogue generation, one key science output will be the study of the quasar demographics. Luminosity function, clustering and higher-order statistics will be made in order to precisely determine the census of quasars, their environments, their host galaxy preferences and their evolution. All these are vital observational tests for galaxy formation models and theory (see WP6 below). The goal of this WP is to make the key observational tests that have to be explained by any viable galaxy formation theory. **WP3 is low-risk, high-reward.** This particular work package will be broken down into smaller projects PDRA 1, PDRA 2, and PhD1 will be directed towards this. There is no element of this which can be deemed high-risk. **Key Deliverables:** A suite of new, beyond-the-state-of-the-art quasar demographic measurements which are the input and boundary conditions for theoretical models.

WP4: LIGHT-CURVE AND SPECTRAL ANALYSES: Another major scientific output that will originate from the quasar corpus catalogue generation will be the full and detailed light-curve and spectral analyses of the said catalogue. This will result in the discovery of light-curve trends with quasar type, new methods to measure black hole mass and the key science goal to see which quasars are "changing-look" objects. This WP will have a data science/machine learning aspect. The goal of this WP is to elucidate the physical processes that drive quasar variability. The full Light-Curve and Spectral Analyses that we envisaged will be a significant amount of work, leading to significant high-reward science. **WP4 is medium-risk, high-reward.** Similar to WP3, this particular work package will be broken down into small projects and PDRA1, PDRA2, as well as the P.I. (NPR) and PhD1 will be directed towards this. This level of investigation is highly novel, though we envisage no major barriers outside of our control to achieving our science goals. As such, we deem this medium-risk. **Key Deliverables:** Measurements, for the first time of how the light-curves and spectra of quasars depend on key physical quasar properties e.g. $M_{\rm SMBH}$, luminosity, $\lambda = \log(L/L_{\rm Edd})$, spin etc. These measurements will allow us to make direct comparisons to accretion disk models.

WP5: ACCRETION DISK SIMULATION: New accretion models are needed to fully explain the observational data of "changing look" quasars that we have examples of today (see e.g. Ross et al. 2018). New radiation MHD codes begin to explain the observations here, but further development is needed to gain the desired deep understanding. The goal of WP5 is to develop new accretion disk simulations that explain our observational results. This will be the lead WP for PDRA3 and a low level of NPRs time. **WP5 is medium-risk, very high-reward.** We classify WP5 not as fully 'low-risk', since we envisage some ramp-up time to get our theoretical simulations to the level that will be required by our beyond-the-state-of-the-art dataset. However, we mitigate this risk by invoking the collaboration with accretion disk theorist Prof. Ken Rice (WKMR) who is the Personal Chair of Computational Astrophysics in the School of Physics and Astronomy at the University of Edinburgh. NPR, WKMR and PDRA3 would thus collaborate on this WP. **Key Deliverables:** New accretion disk models and theory that explain the light curve data of our beyond-the-state-of-the-art dataset.

WP6: QUASAR FEEDBACK SIMULATIONS: Cosmological-scale hydrodynamic simulations are now coming online. While we do not seek to lead or generate new versions of these, we do envisaged using their outputs in order to 'benchmark' our observational demographic work. All the data from these simulations is already in place today, though no one has embarked on doing any of the 'heavy-lifting' and comparisons we will have the observational results for. Professor Romeel Dave (RSD) who is Chair of Physics in the Institute for Astronomy will be a key collaborator here. NPR, RSD and PDRA3 and/or PDRA2 would thus collaborate on this WP. We thus classify **WP6 as low-risk, high-reward. Key Deliverables:** New galaxy evolution models, describing the hydrodynamics involved on galactic scales, but related to the quasar central engine.

WP7: OBSERVATIONS OF QUASARS BY THE JAMES WEBB SPACE TELESCOPE: What are the star-formation properties of mid-infrared luminous quasars at the peak of quasar activity? We aim to answer this by looking for the presence of polycyclic aromatic hydrocarbon (PAH) spectral features in $z \approx 2.5$ infrared bright quasars with the *James Webb Space Telescope* (JWST). **WP7 is high risk, high-reward.** This is an ideal investigation for the JWST, but we classify this as 'high-risk' since this is the one telescope/survey/mission where we have to bid and apply for the telescope time and are not guaranteed the data. We mitigate the risk here by saying that this will be the one project the P.I. (NPR) would lead and does not impact in any direct way the other WPs. This would lead to very-high gain science. **Key Deliverables:** State-of-the-art data and data products from the JWST, with the observational evidence and physical interpretation of how "quasar feedback" regulates galaxy formation in high-redshift quasars.

WP8: NEW OBJECT DISCOVERY: The LSST will scan the sky repeatedly, enabling it, and us, to both discover new, distant transient events and to study variable objects throughout our universe. The most interesting science to come may well be the discovery of new classes of objects. **WP8 is medium-to-high risk, exceptionally high-reward.** We class this as medium-to-high risk, since it is tricky to class a WP with essentially unknown discovery potential as fully 'low-risk'. Suffice to say, this would be exceptionally high-reward **Key Deliverables:** The discovery of new classes of astronomical objects.

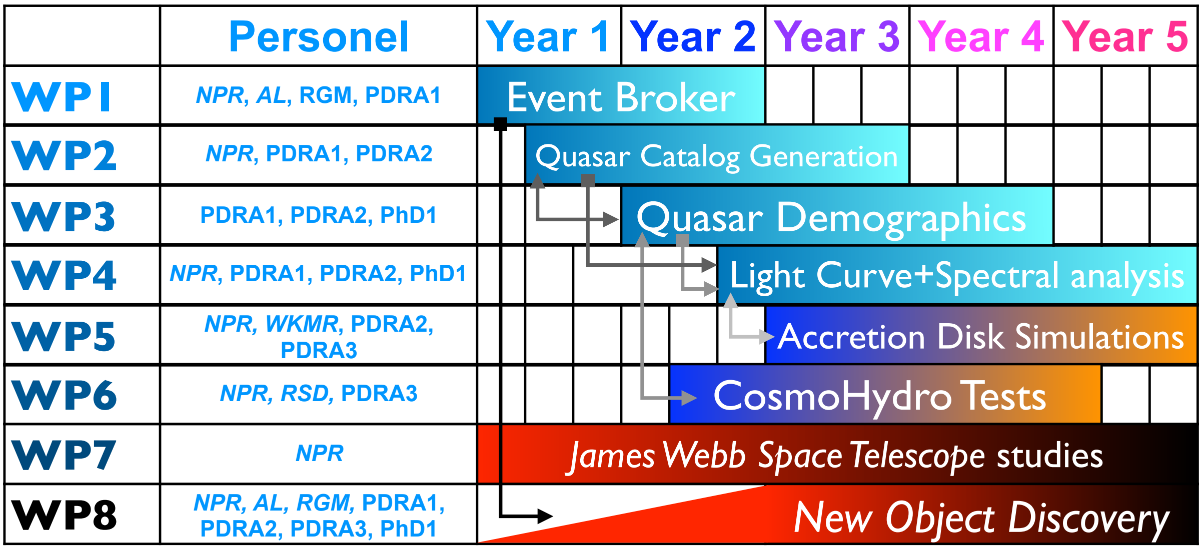

Figure 3: An overview of our WPs: the personel attached to each WP and a guide to their start and duration is shown. The connection between the WPs is also shown, be it generally one-way (square starting points) or an iteration (both ends pointed). As such, the flow arrows are guides and not specifying exact timescales. As given be the shadings, WP1, 2, 3 and 4 are observational studies of large numbers of objects; WP5 and 6 are theoretical modeling investigations and WP7 and 8 are high-risk, very high-reward observational studies of a small number of objects.

3. Resources, Survey 'buy-in' and Budget

PERSONNEL: We request the resources and support for 100% of the time and effort for the P.I. We request the resources and support for 3 Postdoctoral Research Associates (PDRAs), for a total of 10 PDRA year equivalents. This will be broken down as a three year term for PDRA 1, a three year term for PDRA2 and a 4 year term for PDRA 3. We request the resources and support for 1 UK/EU PhD studentship.

SURVEY BUY-IN: We request support for the "buy-in" to two of the new surveys, SDSS-V and DESI. The costs here are \$230,000 (€184,100) for SDSS-V and \$250,000 (€200,100) for DESI. We ask this support to come from the "additional funds that can be made available to cover access to large facilities." We specifically request access to these funds as it gives our project access to telescopes and data in the North and Southern Hemispheres (for complete coverage of the celestial sphere) and delivers the crucial early spectroscopy that will be vital to train, test and build our data science and machine learning codes and algorithms. We emphasise that the science return is 'exponential' (rather than 'linearly') dependent on the breadth of data available and heralds a brand new regime of "several-survey" or "multi-mission" astronomy. *Buy-in here would place the P.I. and the University of Edinburgh as the only group and institute in the world to be involved in SDSS-V, DESI, 4MOST, LSST and ESA Euclid and JWST.*

COMPUTING REQUIREMENTS: With the availability of the facilities at an institute (e.g. IfA Cullen), university (e.g. Edinburgh Compute and Data Facility) and at a national (The Hartree Centre) level, the rate limiting factor will be how quickly and efficiently we can deploy our codes, and analysis.

TRAVEL: We request support for travel for all 5 members of the group, including repeat medium-term (i.e., few weeks) travel to the US and ESO Chile to work with key collaborators at critical timings of the First Light for the new telescopes.

References

R. Davé, M. H. Rafieferantsoa, and R. J. Thompson. mufasa: the assembly of the red sequence. *MNRAS*, 471: 1671–1687, Oct 2017. doi: 10.1093/mnras/stx1693.

A. C. Fabian. Observational Evidence of Active Galactic Nuclei Feedback. *ARA&A*, 50:455–489, Sept 2012. doi: 10.1146/annurev-astro-081811-125521.

Z. Ivezic and J. A. for the LSST Collaboration Tyson. LSST: from Science Drivers to Reference Design and Anticipated Data Products. *ArXiv e-prints*, May 2008.

A. Lawrence. Quasar viscosity crisis. *Nature Astronomy*, 2:102–103, Jan 2018.

LSST Science Collaborations, P. A. Abell, J. Allison, S. F. Anderson, J. R. Andrew, J. R. P. Angel, L. Armus, D. Arnett, S. J. Asztalos, T. S. Axelrod, and et al. LSST Science Book, Version 2.0. *ArXiv 0912.0201v1*, Dec 2009.

C. L. MacLeod, N. P. Ross, et al. A systematic search for changing-look quasars in SDSS. *MNRAS*, 457: 389–404, March 2016. doi: 10.1093/mnras/stv2997.

I. Pâris, P. Petitjean, N. P. Ross, et al. The Sloan Digital Sky Survey Quasar Catalog: Twelfth data release. *Astron. & Astrophys.*, 597:A79, Jan 2017. doi: 10.1051/0004-6361/201527999.

N. P. Ross et al. A new physical interpretation of optical and infrared variability in quasars. *Nature Astronomy*, 2018.

J. Schaye et al. The EAGLE project: simulating the evolution and assembly of galaxies and their environments. *MNRAS*, 446:521–554, Jan 2015. doi: 10.1093/mnras/stu2058.

R. S. Somerville and R. Davé. Physical Models of Galaxy Formation in a Cosmological Framework. *ARA&A*, 53:51–113, Aug 2015. doi: 10.1146/annurev-astro-082812-140951.

M. Vogelsberger, S. Genel, V. Springel, P. Torrey, D. Sijacki, D. Xu, G. Snyder, S. Bird, D. Nelson, and L. Hernquist. Properties of galaxies reproduced by a hydrodynamic simulation. *Nat*, 509:177–182, May 2014. doi: 10.1038/nature13316.

c. Early Achievements Track-record

Nicholas Ross is an STFC Ernest Rutherford Fellow at the University of Edinburgh whose research specializes in implementing algorithms and novel techniques to discover quasars, and studying the physical processes in these extreme extragalactic objects. After just over 7 years in the United States (working at Penn State, the Lawrence Berkeley National Lab and then as an Assistant Research Professor at Drexel University) Nic returned to the U.K. with the award of an STFC Ernest Rutherford Fellowship, the most senior personal astrophysics fellowship in the UK, which has an application oversubscription of ~20:1 and is over £500,000 (€630,000) on award.

Nic's research has involved using the datasets garnered from large astronomical surveys to achieve his science aims and goals. Nic's leadership including leading Science Teams such as the SDSS-III BOSS Quasar Science Working Group has led to him maintaining an extremely high publication output including over 115 peer-review journal articles with 15,000 citations and an *h*-index of 59. This is world-leading for any astrophysicist and virtually unparalleled in his field by his contemporaries at a similar career stage. A brief summary of Nic's research contributions is given below with an emphasis on areas specifically related to the current proposal.

Nic has been involved in the discovery of two new types of extragalactic objects. He discovered the **Extremely Red Quasars**, a unique obscured quasar population with extreme physical conditions related to powerful galaxy-scale outflows. Dr Ross also co-led the first systematic search for **Changing Look Quasars,** quasars that exhibit dramatic changes in their observed properties over the course of only weeks to years. They are important since they offer a direct observational probe into the physical processes of the inner galactic central engine.

Data Science: Dr. Ross has become an expert in a suite of research methodologies that encompass what is now general taken to be and called data science and machine learning. In particular, at the heart of Dr. Ross's research with the SDSS-BOSS project, was essentially anomaly detection in extremely large datasets. This was achieved by employing a set a machine learning tools and algorithms. Dr. Ross was a co-founder and Chief Data Scientist of, **String Security *Inc.*** a tech start-up based in the San Francisco Bay Area. There he built a predictive threat detection and remediation platform for cyber security teams by applying novel machine learning and predictive algorithms. Nic left String Security after the start-up pivoted to the cyber insurance market, but the techniques, experience and professional network that he built up is a critical basis of the current ERC Consolidator proposal.

Relevant Selected Journal Publications

Pâris, Isabelle; Petitjean, Patrick; **Ross, Nicholas P.** and 43 co-authors, *The Sloan Digital Sky Survey Quasar Catalog: Twelfth data release,* 10.1051/0004-6361/201527999, **2017A&A...597A..79P** **88 citations**

Hamann, Fred; Zakamska, Nadia L.; **Ross, Nicholas;** and 12 co-authors, Extremely red quasars in BOSS, 10.1093/mnras/stw2387, **2017MNRAS.464.3431H**, **13 citations**

Timlin, John D.; **Ross, Nicholas P.** and 19 co-authors, *SpIES: The Spitzer IRAC Equatorial Survey,* 10.3847/0067-0049/225/1/1 **2016ApJS..225....1T**, **13 citations**

MacLeod, Chelsea L.; **Ross, Nicholas P** and 11 co-authors, *A systematic search for changing-look quasars in SDSS,* 10.1093/mnras/stv2997, **2016MNRAS.457..389M**. **42 citations**

Ross, Nicholas P. and 12 co-authors Extremely red quasars from SDSS, BOSS and WISE: classification of optical spectra, **2015MNRAS.453.3932R**, 10.1093/mnras/stv1710, **25 citations**

Font-Ribera, Andreu; Kirkby, David; Busca, Nicolas; Miralda-Escudé, Jordi; **Ross, Nicholas P.** and 38 co-authors, *Quasar-Lyman α forest cross-correlation from BOSS DR11: Baryon Acoustic Oscillations,* 10.1088/1475-7516/2014/05/027 **2014JCAP...05..027F** **164 citations**

Pâris, Isabelle; Petitjean, Patrick; Aubourg, Éric; **Ross, Nicholas P.**; and 46 co-authors, *The Sloan Digital Sky Survey quasar catalog: tenth data release* 10.1051/0004-6361/201322691 **2014A&A...563A..54P** **153 citations**

Ross, Nicholas P. and 41 co-authors, *The SDSS-III Baryon Oscillation Spectroscopic Survey: The Quasar Luminosity Function from Data Release Nine,* 2013, 10.1088/0004-637X/773/1/14 **2013ApJ...773...14R, 98 citations**

Ross, Nicholas P and 38 co-authors, *The SDSS-III Baryon Oscillation Spectroscopic Survey: Quasar Target Selection for Data Release Nine,* 2012, 10.1088/0067-0049/199/1/3, **2012ApJS..199....3R** **177 citations**

Pâris, I.; Petitjean, P.; Aubourg, É.; Bailey, S.; **Ross, Nicholas P.** and 70 co-authors
The Sloan Digital Sky Survey Quasar Catalog: Ninth Data Release, 10.1051/0004-6361/201220142
2012A&A...548A..66P **182 citations**

Schneider, Donald P.; Richards, Gordon T.; Hall, Patrick B.; Strauss, Michael A.; Anderson, Scott F.; Boroson, Todd A.;, **Ross, Nicholas P.** and 41 co-authors; *The Sloan Digital Sky Survey Quasar Catalog. V. Seventh Data Release,* 10.1088/0004-6256/139/6/2360
2010AJ....139.2360S **585 citations**

Ross, Nicholas P et al. *"The SDSS-III Baryon Oscillation Spectroscopic Survey: Quasar Target Selection for Data Release Nine"*, 10.1088/0067-0049/199/1/3, **2012ApJS..199....3R**, **178 citations**

Ross, Nicholas P et al. *"Clustering of Low-redshift (z <= 2.2) Quasars from the Sloan Digital Sky Survey,* 10.1088/0004-637X/697/2/1634, **2009ApJ...697.1634R** **158 citations**

Ross, Nicholas P et al. *"The 2dF-SDSS LRG and QSO Survey: the LRG 2-point correlation function and redshift-space distortions"*, 10.1111/j.1365-2966.2007.12289.x **2007MNRAS.381..573R**, **180 citations**

PRIZES AND AWARDS

2014 - 2019	STFC Ernest Rutherford Senior Fellowship
2009 - 2016	*Architect* SDSS-III: Baryon Oscillation Spectroscopic Survey (BOSS)
2003 - 2008	PPARC Student Fellowship, *Durham University*

SELECT LEADERSHIP

2014 - 2019	P.I., STFC Ernest Rutherford Fellowship
2013 - 2016	Primary Co-I, *Spitzer Space Telescope,* Cycle 9 GO program "SpIES: The Spitzer-IRAC Equatorial Survey""
2012 - 2014	Scientific P.I., *Hubble Space Telescope,* Cycle 20, "The Host Galaxies of High-Luminosity Obscured Quasars at z~2.5"
2011	Chapter Editor, *BigBOSS* NOAO Proposal, arxiv.org/abs/1106.1706v1
2011	P.I., SDSS-IV: BOSS-Plus (accepted Nov 2011; merged into SDSS-IV: eBOSS)
2009 - 2012	Chair, SDSS-III BOSS Quasar Working Group
2008 - 2010	Lead, SDSS-III BOSS Quasar Target Selection Group

2008 - 2010 P.I., NASA *Swift* Cycle 5 Long-term local AGN monitoring program

RECENT SELECTED PRESENTATIONS

2014 May	Harvard University	HEAD talk
2014 April	Drexel University	Physics Colloquium
2014 April	University of Pennsylvania	Astrophysics Seminar
2014 March	Princeton University	Invited talk, "Heritage of Stripe 82" meeting
2013 November	University of Florida	Colloquium
2013 July	Durham University	"Ripples in the Cosmos" conference
2013 May	Stanford University	KIPAC Tea Talk
2013 January	University of Washington	Colloquium
2012 July	Durham University	ICC, Seminar
2012 April	UC, Irvine	Seminar
2012 April	Trieste, Italy	"Interacting Galaxies and Binary Quasars"
2012 January	New York University	Plenary Talk, BOSS Collaboration meeting
2011 November	UC, Santa Cruz	FLASH Seminar
2011 July	Oxford University	BICAP Cosmology Seminar
2011 May	Yale University	YCAA Seminar
2010 October	IMPU, Tokyo	Galaxies and AGN Workshop
2010 September	Cambridge University	IoA Seminar

EDUCATION

2003 - 2007 Ph.D. in Astrophysics, **University of Durham**, U.K.
"*The Clustering and Evolution of Massive Galaxies*"
Advisor: Prof. Tom Shanks

1999 - 2003 M.Sci., Physics & Astronomy, **University of Durham**, U.K.
First Class Honours, Fourth Year Advisor: Prof. Shaun Cole

POSITIONS

2016 - 2017 Chief Data Scientist
String Security, Inc., San Francisco, USA

2014 - STFC Ernest Rutherford Fellow
University of Edinburgh, U.K.

2013 - 2014 Research Assistant Professor
Drexel University, U.S.A., Advisor: Prof. Gordon T. Richards

2009 - 2013 Postdoctoral Researcher/Project Scientist, Berkeley Cosmology Group
Lawrence Berkeley National Lab, U.S.A., Advisor: Dr. David. J. Schlegel

2007 - 2009 Postdoctoral Research Scholar, Dept. of Astronomy and Astrophysics
Pennsylvania State University, U.S.A., Advisor: Prof. Donald. P. Schneider

FELLOWSHIPS AND AWARDS

2014 – 2019 Science & Technology Facilities Council
Ernest Rutherford Fellowship
Senior Research Fellowship, *University of Edinburgh*

PUBLICATION RECORD

Author on 118 published papers	Total number of citations:	14,942	(126.6 citations/paper)
First author on 6 published papers	Total number of citations:	640	(106.7 citations/paper)

h-index of 59.

GRANTS/FUNDING OBTAINED

STFC Ernest Rutherford Fellowship (PI.)	$831,481
NASA *Spitzer Space Telescope* Cycle 9, 820 hours (Lead Co-I)	$440,163
NASA *Hubble Space Telescope* Cycle 20, 18 orbits (P.I.)	$106,852
NASA *Swift* XRT and UVOT ToO observations, Cycle 5, 17.8ks (P.I.)	$34,039
Chandra Cycle 12 Co-I Archival proposal "The Dark Matter-AGN-Weak Lensing connection" (co-I)	$51,281

SUPERVISION

2015- **David Homan**
University of Edinburgh PhD student

2015 **Thomas Kemp**
University of Edinburgh MSc student

2013 - **John Timlin**
Drexel University Graduate Student, Philadelphia PA, USA
(On Ph.D. Dissertation Committee)

2013 - 2014 **Victoria Tielebein**
Drexel University Senior Thesis Student, Philadelphia PA, USA

2009 - 2012 **Jessica Kirkpatrick**
UC Berkeley Graduate Student, Berkeley CA, USA

2009 - 2010 **Rachel Kennedy**
UC Berkeley Honors Student, Berkeley CA, USA
2008 - 2009 **Michael Peth**
Pennsylvania State University Honors Student, State College PA, USA

APPOINTMENTS AS EXTERNAL EXAMINER

2016 **Ben Chehade, PhD, "***The luminosity and redshift dependence of quasar clustering"*, University of Durham
2016 **Behzad Ansarinejad, M.Res**, *"An Empirical Analysis of Baryon Acoustic Oscillations in Galaxy and Quasar Clustering"*, University of Durham

TEACHING ACTIVITIES

2015, 2016 Joint Instructor, *Introduction to Astrophysics*, University of Edinburgh
2009 Lead Instructor, *Astro 010: Introduction to Astronomy*, Penn State University
2007 Postgraduate Instructor, *Stars and Galaxies* course, Durham University

ORGANISATION OF SCIENTIFIC MEETINGS

2017 **Co-Chair SOC** *Unveiling the Physics Behind Extreme AGN Variability*
University of the Virgin Islands, St. Thomas, U.S. Virgin Islands.
2016 **Chair S/LOC** *JWST@ROE* University of Edinburgh, International meeting
2015 **Chair S/LOC** *Quasar Day* University of Edinburgh, National meeting,
2014 **SOC Member** *Multi-wavelength Heritage of Stripe 82 Workshop*, Princeton University
2011 **SOC Chair** *SDSS-III BOSS Quasar Working Group* meeting, Princeton University

COMMUNITY SERVICE

Referee *Physical Review Letters*
Monthly Notices of the Royal Astronomical Society
The Astrophysical Journal
The Astronomical Journal
Journal of Cosmology and Astroparticle Physics
Reviewer for the NASA Postdoctoral Fellowship Program
Session Chair, "Wide-Field Surveys and QSO Physics" Parallel, UK National Astronomy Meeting, 2015.
Founder "Astronomers for America" and "Scots for Science"

MEMBERSHIPS OF SCIENTIFIC SOCIETIES

Fellow Royal Astronomical Society (since July 2004)
Full Member American Astronomical Society, (since Nov 2009)
Founder "Astronomers for America"

PRESS RELEASES

2012 BOSS Lyman-α Forest BAO Detection (incl. image credit)
2012 Quasar Broad Absorption Line Disappearance
2009 SDSS-III: BOSS First Light

SELECTED OUTREACH

2015, 2016 ROE Open Day
2013, 2014 Public Observing Nights, Drexel University
2012 LBNL Open House
2008, 2009 Penn State In-Service Workshop in Astronomy
2008, 2009 Penn State Astronomy and Astrophysics annual "AstroFest"

Appendix: All on-going and submitted grants and funding of the PI (Funding ID)
Mandatory information (does not count towards page limits)

On-going Grants

Project Title	*Funding source*	*Amount (Euros)*	*Period*	*Role of the PI*	*Relation to current ERC proposal*
STFC Ernest Rutherford Fellowship (ERF)	STFC, U.K.	674,663	01-OCT-2014 to 30-SEP-2019	To perform world leading research, either independently, or with collaborators of the PIs choice.	Current ERF grant has research linked to, but not overlapping with ERC proposal. ERC proposal would build-on, and is a novel extension to, the current research programme.

Grant applications

n/a