'AGN UK Community Meeting (AGNUK)' Abstracts

Talks

A library of predicted emission maps as a connection between simulations of AGN jets and observable properties

Authors

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Abstract

Relativistic magnetohydrodynamic simulations are a key tool for understanding resolved radio images of AGN jets. Whilst observations can only be made from a single angle and for a single snapshot in each individual radio galaxy's development, simulations allow us to see the evolution of a radio galaxy from all angles.

We present a library of Doppler-boosted pseudo-emissivity maps produced from our simulation data at different times in the simulation, with a particular focus on the viewing-angle dependence of the images. Our libraries of images show that viewing angle can highlight vastly different features of a given jet and demonstrate that emissivity maps from simulations can help to build intuition about how jet morphologies can develop over time. With the aims of facilitating the use of these images and encouraging other simulators to consider producing similar libraries of images, we give an overview of two methods for making pseudo-emissivity maps from hydrodynamic simulations.

Overall, we hope to facilitate more effective discussion between observers and theorists working on simulations, by making the results of simulations accessible in a format that mirrors observational results.

AGN Science with the Rubin Observatory's Legacy Survey of Space and Time

Authors

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Abstract

I will present the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST), and discuss some of the many ways in which LSST can be used for AGN studies. In particular I will highlight opportunities for the UK community, and some challenges which need to be addressed collaboratively to maximise AGN science with Rubin data.
Starting in 2026, LSST will produce a time-series of 6-band multi-colour photometric information observed every 2-3 nights to 24th magnitude over the full southern sky. Over the course of the nominal 10-year survey, LSST will detect more than 100 million AGN, making it the ideal data-set to conduct a deeper census of black hole growth across cosmic time, coupled with low-surface brightness sensitivity to simultaneously probe the properties of their host galaxies. By quantifying the photometric variability in tens of millions of AGN, we will be able to place new constraints on the structure of SMBH accretion discs, as well as detecting more exotic phenomena such as changing-look AGN.

Exploring dusty AGN in the era of large spectroscopic surveys

Authors

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Abstract

In the past 10 years, the wealth of extragalactic spectroscopic data has increased exponentially, from the early Sloan Digital Sky Survey (SDSS) data releases to the vast data continually being released from the Dark Energy Spectroscopic Instrument (DESI). The 4-metre Multi-Object Spectroscopic Telescope (4MOST), which recently completed comissioning, will observe fainter and more obscure AGN than both DESI and SDSS. Furthermore, the upcoming Multi-Object Optical and Near-IR Spectrograph (MOONS), due to have first light on the VLT ~end of 2026, will also open up a new window of spectroscopic studies, probing the NIR spectra of thousands of AGN. The UK has played a major role in all of these spectroscopic surveys, with several UK institutes being part of the DESI survey, Durham and Cambridge Universities playing a key role in the 4MOST AGN survey, and the MOONS instrument built at the University of Edinburgh. In this talk, I will present my research exploring the radio and spectroscopic properties of dusty quasars, utilising data from both SDSS and DESI. I will also talk about my current and future involvement in the MOONRISE survey and will present potential collaborative projects utilsing the vast amount of public spectroscopic data already available.

MIGHTEE: the dark matter haloes, duty cycle, and mechanical feedback from radio-AGN up to z ~ 2.5

Authors

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Abstract

Radio-AGN are more strongly clustered than non-active galaxies, but it remains unclear whether this is simply due to their preference for massive host galaxies, or if they occupy distinct environments beyond this mass dependence. I will present work investigating how the dark matter environment may be related to radio-AGN activity by studying the clustering of ~2000 radio-AGN in the MIGHTEE survey out to z=2.5. To test if AGN inhabit different dark matter halo environments, we compare to a control sample of galaxies matched in redshift and stellar mass. The AGN still show a clear clustering excess, so host mass alone cannot account for the difference. Using Halo Occupation Distribution (HOD) modelling to estimate the properties of the dark matter haloes hosting these sources, we measure galaxy bias (a measure of how strongly galaxies trace the underlying matter density field), find typical halo masses of the order $10^{13}\ {\rm M_\odot}$ that increase with cosmic time, and estimate duty cycles of 5-9 per cent. Importantly, AGN are found to reside in haloes that are 1.1-1.8 times more massive than those of the stellar mass-matched control galaxies. This difference may be due to AGN feedback suppressing stellar mass growth while leaving halo mass unchanged, or because radio-AGN preferentially inhabit earlier-forming, more strongly clustered haloes.

From spherical cows to asymmetric dinosaurs: astrophysical jets and a new numerical approach to modelling their emissions.

Authors

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Abstract

The modelling of astrophysical jets has traditionally taken one of two approaches: macroscopic or microscopic. The former examines the large-scale structure and dynamics (e.g. GRMHD), while the latter focuses on the small scales of particle interactions (e.g. one-/multi-zone models). Each approach captures only part of the picture, but both perspectives are required to fully describe how these jets are formed, launched, and emit the multi-messenger signals through which we observe them. To bridge these two approaches, I will present DIPLODOCUS, a framework for general particle transport and emission modelling of astrophysical sources, capable of the self-consistent inclusion of large-scale spatial structure and small-scale anisotropic particle interactions. This will include an overview of the framework and its associated open-source code implementation, Diplodocus.jl; verification of its capability through relevant tests and code comparisons; and an exploration of its use in studying particle creation, acceleration, and emission within the acceleration region of an AGN jet.

Radio Galaxy Zoo: morphological classification by Fanaroff-Riley designation using self-supervised pre-training

Authors

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Abstract

In this talk, I will present a morphological analysis of over 14,000 radio galaxies selected from the Radio Galaxy Zoo (RGZ) project, including classifications for approximately 5,900 Fanaroff-Riley Class I (FRI) and 8,100 FRII sources. The sources were classified using a pre-trained radio galaxy foundation model that was fine-tuned for morphological classification. The overlap in luminosity-size distributions between machine learning-classified FRI and FRII sources aligns well with prior studies. However, the model's confidence in its predictions is lowest in this overlap region, suggesting that source morphologies are more ambiguous.
We investigate the impacts of pre-training and fine-tuning data selection on model performance for the downstream classification task and show that while different pre-training data choices affect model confidence, they do not appear to cause systematic generalisation biases for the range of physical and observational characteristics considered in this work; however, we note that the same is not necessarily true for fine-tuning. We highlight training data choices that can affect the model outputs and propagate into downstream analyses. We analyse the density evolution and radio luminosity function (RLF) for these sources, discuss whether RLFs derived from machine-learning classifications differ from those built using more conventional approaches, and consider if AI-driven classification methods could provide a different scientific interpretation of galaxy evolution.

The DESI AGN/Galaxy Classification VAC

Authors

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Abstract

The Dark Energy Spectroscopic Instrument (DESI) survey has observed over 18 million spectra as part of the first data release (DR1), including more than 14 million extra-galactic sources. Classification of galaxies into active or inactive, star-forming or quiescent, is a complex process with many degeneracies. In our value added catalog (VAC), we provide separate classification flags for over a dozen selection methods including nine narrow optical spectroscopic emission-line diagnostics, six infrared color selection methods, and use four major broad permitted emission lines present in the DESI spectra. Many objects will be identified as Active Galactic Nuclei (AGN) according to one diagnostic but star-forming (SF) in another, and this VAC allows researchers to explore this complexity in their work, by selecting objects based on a single relevant criterion, or cross-referencing between many criteria to produce more complete samples. This public catalog is designed to be a treasury-level resource to support a multitude of AGN and galaxy evolution studies from the local universe out to $z \leq 3.5$. In this presentation, we describe the construction of the catalog, discuss the known limitations and caveats, and present how to access and utilise this publicly available dataset with an example science case.

Posters

Semi-empirical constraints on the high-z SMBH population and the implications for their early evolution.

Authors

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Abstract

JWST observations have unveiled a numerous population of low-luminosity active galactic nuclei (AGN) at $4 \lesssim z \lesssim 10$, many of which have masses orders of magnitude above the local black hole mass--stellar mass ($M_{\rm BH}-M_{*}$) scaling relations. These high-z measurements question the consistency of this previously unobserved population with our understanding of supermassive black hole (SMBH) evolution at both earlier and later times. By modelling the SMBH population and their host galaxies from $z = 10$ to present day within the semi-empirical model DECODE, we examine the conditions necessary to reproduce the AGN population observed by JWST at $z \sim 5 – 6$, and the implications of this on the later evolution of SMBHs.
Specifically, in DECODE, galaxy growth is associated to the growth of the host halo via the star-formation rate – halo-accretion rate relation, and SMBHs are grown within these via the observed Eddington ratio distribution. Galaxy and SMBH mergers are included self-consistently in accordance with the dark matter merger trees. By tuning the extrapolation of the Eddington ratio distribution at $z>6$ to match different estimates of the AGN luminosity function, we can constrain the accretion rates and duty cycles needed to match the high-z observations from JWST. In this poster, I will present the high-z evolution of the SMBH-galaxy scaling relations and SMBH mass function resulting from our modelling, and the implications for our picture of SMBH-galaxy coevolution at later times. We find that whether or not the AGN observed by JWST are assumed to be representative of the underlying SMBH population leads to consistent z~0 predictions, but distinct evolutionary pathways and merger contributions, which has implications for the gravitational wave background.

Too many or too massive? Investigating the high-z demography of active SMBHs from JWST

Authors

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Abstract

Recent JWST observations have unveiled a numerous population of low-luminosity active galactic nuclei (AGN) at $4 \lesssim z \lesssim 10$, with space densities roughly an order of magnitude above pre-JWST estimates, and many of these AGN have masses orders of magnitude above the local black hole mass–stellar mass ($M_{\rm BH}-M_{*}$) scaling relations. We investigate the consistency of these observations within a data-driven framework that links the galaxy stellar mass function to the supermassive black hole (SMBH) mass function and AGN luminosity functions using different $M_{\rm BH}-M_{*}$ relations and the observed Eddington-ratio distribution. By comparing our predictions against observed AGN luminosity functions at $z\sim 5.5$ we find that observations can be reproduced either by highly-elevated $M_{\rm BH}-M_{*}$ relations paired with low duty cycles ($f_{\rm AGN} \sim 0.08$), or moderate relations with higher duty cycles ($f_{\rm AGN} \sim 0.5$). Through the Sołtan argument, we find that $M_{\rm BH}-M_{*}$ relations that are modestly above the local relation for AGN produce consistency between multiple tracers of the SMBH demography at $z\sim 5.5$, while more extreme normalisations would require a weakly-evolving luminosity function at $z\geq 5.5$. Continuity-equation modelling shows that initially high $M_{\rm BH}-M_{*}$ relations predict a strong two-phase evolutionary scenario and very steep low-mass SMBH mass functions in tension with several current estimates, while more moderate relations generate local SMBH mass functions in better agreement with present determinations and near-constant scaling relations. Our results favour a scenario where SMBHs at $z\sim 5$ on average lie modestly above local AGN scaling relations, with elevated but physically plausible duty cycles. Future wide-field clustering and demographic studies will help break the remaining degeneracies between SMBH scaling relations and AGN duty cycles at early cosmic times.

The importance of AGN-induced shocks for accelerating outflows and recycling the ISM

Authors

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Abstract

Despite being thought to play a key role in the regulation of star formation on galactic scales, it remains unclear exactly how outflows of gas are accelerated by AGN and to what extent they impact their host galaxies. To directly address this, we have taken detailed, spatially-resolved spectroscopic observations of the warm ionised (T~10,000 K) outflows in the kiloparsec-scale radio lobe of the nearby Seyfert galaxy NGC 1068. Despite being one of the most well-studied AGN, there is considerable debate regarding how the multi-phase outflows in this object are launched.

We find evidence that the gas is compressed during the acceleration process and its dust grains are efficiently destroyed. This is consistent with shock acceleration, driven either by the AGN jet or fast accretion-disk winds. Consequently, the other phases of outflowing gas that have been observed in NGC 1068 can be explained as part of a post-shock cooling sequence. I will present the observational diagnostics that we developed for our analysis, which provide clear tracers of shocks and AGN activity and are broadly applicable across AGN studies. Overall, our results support a scenario in which outflows are accelerated by jet-induced shocks - which can explain the link between the different gas phases - and highlight the importance of this process in the evolution of the near-nuclear regions of galaxies.

Low-Frequency Radio Morphologies and Multi-Frequency SED Modelling of 3CRR Radio-Loud AGNs

Authors

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Abstract

Radio-loud AGNs are characterised by the presence of collimated, relativistic jets of plasma launched from the supermassive black hole at their centre. They make up a minority of AGN populations, but offer insight through their extended emission within the radio regime. The main emission mechanism within the jets is synchrotron, where magnetic field lines, which confine the plasma, cause free electrons to be accelerated to relativistic velocities, releasing synchrotron radiation commonly observed within the radio regime. Although this is seen across radio-loud AGNs, differences in their structure, host galaxy properties and environment along with their broadband emission across the entire electromagnetic spectrum offer insight into the complex physical mechanisms at play in these cosmic species. To resolve them, there is the need to model their spectral energy distribution (SEDs) effectively, using high-resolution and sensitivity data to allow for effective separation of the different emission processes. For example, emission from jets, winds and outflows and/or star formation.

In this work, we utilise a sample of 12 extragalactic radio sources selected from the 3CRR catalogue for which there exists a wealth of multi-frequency and multi-wavelength (radio to X-ray) data. Our primary sample is taken from the LOFAR LoTSS DR3. We explore the morphological properties in our sample and show features never seen before at such low frequencies for some sources in our sample. We combine our LoTSS DR3 data with GMRT Band 4, VLA First and VLASS to model the radio SEDs. We also combine our multi-frequency radio data with WISE, HST and Chandra to model the multi-wavelength SEDs in our sample to a new depth. I will present initial results from our morphological and SED analysis, and provide insights into our future work that will employ our SED analysis to a larger sample of AGN populations within the GAMA G09 equatorial field, utilising data from ASKAP, LOFAR and MeerKAT facilities.

From Ultra-Fast Winds to Galaxy-Scale Feedback: a multi-phase energy-conserving outflow in IRAS 17020+4544

Authors

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Abstract

Outflows are crucial to AGN feedback, transporting mass and energy from the nucleus to the host galaxy across various scales. Theoretical models suggest that sub-relativistic Ultra Fast Outflows (UFOs), which interact with the ISM, decelerate and lose ionization, potentially driving large-scale, multi-phase outflows observable in optical and molecular gas.
The Narrow Line Seyfert 1 galaxy IRAS 17020+4544 offers a rare local laboratory to study AGN-driven outflows in action. It hosts a complex X-ray Ultra Fast Outflow (UFO), a powerful cold molecular outflow spatially resolved in CO with NOEMA millimeter observations, and a low-power radio jet that may be driving shocks into the interstellar medium (ISM).
In this work, we present MEGARA/GTC optical IFU observations of the ionized gas component over an area of ~140 kpc^2, within the region covered by the molecular outflow. We perform a detailed kinematic and energetic analysis of the ionized outflow and compare it from X-ray to mm bands.
We find that the ionized phase is consistent with an "energy-conserving" regime, in agreement with previous results for the molecular component (Longinotti et al. 2023).
These findings indicate that the different gas phases are dynamically coupled and support a scenario in which powerful AGN-driven winds efficiently transfer energy to the host galaxy. Intriguingly, we also find evidence of positive feedback in the central regions, suggesting that the outflow may not only expel gas but also compress it, potentially triggering star formation. Overall, our results provide new insight into the multi-phase nature of AGN feedback and its impact on the evolution of Narrow-Line Seyfert 1 galaxies.
IRAS 17020+4544 thus stands out as one of the very few systems in which a multi-phase outflow associated with a UFO is observed to follow an "energy-conserving" regime across different gas phases, offering a rare benchmark for testing AGN feedback models.

Properties of Optical Variability-selected AGN in massive galaxies within VST-COSMOS: insights for future LSST science

Authors

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Abstract

We study the properties of 56 massive (M > 10 M) galaxies at that host AGN, detected via their broad-band optical variability in the VST-COSMOS survey. VST-COSMOS provides a nearly identical single visit depth (r~24.6 mag) and temporal baseline (eleven years) as the forthcoming Legacy Survey of Space and Time (LSST), albeit in a much smaller 1 deg footprint (four orders of magnitude smaller than that of the LSST). We compare the properties (morphologies, the presence of interactions, rest-frame colours and environment) of our AGN to galaxies in a control sample, which are drawn from the non-variable population and matched in redshift and stellar mass to their AGN counterparts. The fraction of AGN with early-type morphology (~55 per cent) and the fraction that is interacting (~23 per cent) are similar to what is observed in the controls, suggesting that these AGN are not primarily triggered by interactions. Similarly, the AGN and controls do not show strong differences in their rest-frame(u-z) colours or local environment, suggesting that neither the recent star formation histories nor the surroundings of the AGN are strongly atypical of the general galaxy population. This study provides a glimpse into forthcoming AGN science using the LSST. With vastly improved statistics, LSST will offer unprecedented insights into AGN demographics, host-galaxy evolution and the processes that fuel supermassive black holes, potentially reshaping our understanding of their place in the Universe.

Multi-Wavelength AGN Identification and Physical Parameter Estimation using machine learning in DESI survey.

Authors

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Abstract

Active Galactic Nuclei (AGN) play a key role in galaxy evolution, but identifying a complete, unbiased sample is complicated because it requires extensive, multi-wavelength detections. To address this, we apply a machine learning framework to the Dark Energy Spectroscopic Instrument (DESI) survey, utilizing the available rest-frame UV and optical range (3600–9800 Å) to leverage established, precise AGN classification methods.

Our methodology employs SPENDER, an unsupervised machine learning framework, to compress galaxy spectra into a multi-dimensional latent space. Using a classifier algorithm on a curated, balanced and diverse sample of galaxy spectra—spanning $0 < z < 3.5$, our framework achieves an AGN detection rate exceeding 75%. By analyzing the topology of the latent space, we isolate the specific spectral features driving classification and examine AGN co-evolutionary tracks that are typically obscured in standard projections. Furthermore, we perform traversals of the latent space, stacking spectra within local neighborhoods to study the transition of galaxy properties across different types of galaxies in our dataset. This process helps us understand the regions of confusion/misclassification with the classification algorithms, as the latent representation captures complex, non-linear behaviour of galaxy spectra.

Finally, we employ a Bayesian inference pipeline that maps the purely mathematical latent space to fundamental physical spectral properties, such as stellar mass, metallicity, age, and other parameters, derived from DESI survey. This approach serves as a high-speed, scalable infrastructure alternative to the traditional Spectral Energy Distribution (SED) fitting. Such an efficient methodology makes it suitable for the massive datasets anticipated in future DESI, and other wide-area spectroscopic surveys.