'From horizon to galaxy and beyond: the role of jets, winds and outflows in AGN (WindsAGN)' Abstracts

Talks

Simulating the morphology of variable power magnetised AGN jets

Authors
Emma Elley (1), James Matthews (1)

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Abstract
Title: Simulating the morphology of variable power magnetised AGN jets
Large sky radio surveys show jets with a wealth of diverse morphologies resulting from complex interplays between magnetic fields, jet powers and environmental factors. Simulations are an invaluable tool for building understanding of these systems and the ways in which the morphology of a jet can transform over time.
We present relativistic magnetohydrodynamic simulations of AGN jets with flickering power, motivated by the variability in accretion rate predicted by chaotic cold accretion of hot gas. We use the PLUTO code. Our results show that moderate variability can have strong impacts on the morphology of magnetised jets, with significant changes during the lifetime of a single jet.
To facilitate comparison with observations we show pseudo-emissivity maps from a variety of angles to the line of sight, including the effects of Doppler boosting. These emissivity maps reproduce some of the features observed in spatially resolved radio images.
Overall, we show that variability in jet power has crucial effects on the morphologies of individual radio galaxies over time and could play a key role in creating the diversity in observed sources. This has important implications for the way in which we interpret results from surveys over full populations.

Understanding the triggering of near-by radio-loud AGN

Authors

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Abstract

The expanding jets and lobes of powerful, radio-loud AGN are associated with one of the most important forms of feedback, directly affecting the star formation histories of host galaxies and influencing the shape of the galaxy luminosity function. Understanding how they are triggered is key to properly incorporating radio AGN into models of galaxy evolution. They can be characterised by their accretion modes, with the radiatively-efficient radio AGN (e.g. HERGs) accreting at a high Eddington rate (>1%), in contrast with their radiatively-inefficient counterparts (e.g. LERGs) at much lower Eddington rates. Previous studies have suggested that the dominant triggering mechanisms vary between these subtypes, but at low levels of statistical significance. We present the results of a deep INT/WFC imaging survey which, when combined with Gemini/GMOS-S images, gives a 98 per cent complete sample of 112 3CR radio galaxies with redshifts z < 0.3, alongside a stellar mass matched control sample. Our results provide strong evidence for significant differences (~3σ) between the triggering mechanisms of the different subtypes of powerful radio AGN. The HERGs show a high rate of morphological disturbance – an excess of ~4σ compared with the control sample – consistent with them being predominantly triggered in galaxy mergers and interactions. In contrast, the LERGs show a much lower rate of morphological disturbance, consistent with the control sample, and suggesting a different triggering mechanism, such as the accretion of gas from the hot X-ray haloes of the host galaxies or galaxy clusters. We also demonstrate that, when considering their radio morphology, the FRII HERG sources preferentially reside in disturbed morphologies, a difference of ~3σ to the FRII LERG objects. This suggests that the FRII LERG sources do not solely represent a 'switched-off' phase in the HERG lifecycle of the same parent galaxy population as the FRII HERGs.

Relic outflows in z > 3 quiescent galaxies

Authors

Elizabeth Taylor (1)

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Abstract

Galactic scale outflows are a signature of feedback processes, and high-velocity winds are common in star-forming and recently-quenched galaxies at $z < 1$. However, there is still a lack of consensus on if these winds are directly linked to the quenching event itself. In this talk, I will outline our work investigating outflows in recently-quenched and quiescent galaxies at cosmic noon and beyond, in an attempt to constrain the cause of quenching in high-redshift systems. We investigate the presence and origin of neutral gas outflows and inflows in 13 post-starburst (PSB) and quiescent galaxies at redshifts 1.8 ≤ ▯ ≤ 4.6, using JWST NIRSpec spectroscopy from the EXCELS survey. Na d absorption profiles reveal that 3 out of 13 exhibit blueshifted absorption indicative of outflows, and a further 2 objects show signs of inflowing gas. Outflow velocities range from ≈ 300 – 1200 $\mathrm{km\ s^{-1}}$, and gas flows are detected exclusively in objects that quenched < 600 Myr ago. We compare outflow energetics to those expected from star formation and AGN activity, ultimately finding that we are likely observing fossil outflows driven by previous, more luminous AGN activity which has since faded. Finally, I will present a simple estimation of a potential 'AGN-outflow cycle', derived from comparison of our observations to simulations.

Linking AGN winds and outflows from nuclear to ISM scales

Authors

Matthew Temple (1)

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Abstract

Understanding the connection between different outflow phases is key to understanding AGN feedback. Here we compile a large sample of uniformly-measured [OIII] 5008A outflow observations for luminous AGN at cosmic noon, and test how broad absorption line (BAL) troughs from fast-moving nuclear outflows in the rest-frame ultraviolet are linked to the narrow line region outflows seen from larger-scale, lower-density gas the rest-frame optical. The strength and velocity width of [OIII] are found to correlate strongly with the CIV emission-line blueshift, but no significant difference is seen between the [OIII] properties in our sample of 73 BAL, 115 miniBAL, and 125 non-BAL quasars once the dependence on CIV emission is taken into account. Our results add to the growing evidence that BALs and non-BALs are drawn from the same parent population and are consistent with a scenario wherein BAL troughs are intermittent tracers of persistent quasar outflows, with a part of such outflow becoming optically thick along our line of sight for sporadic periods of time within which BALs are observed.

Bridging the power gap in jet-driven feedback: 3C 15 is not like the others

Authors

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Abstract

AGN feedback covers a wide range of spatial and temporal scales, from the accretion flows fuelling the central black hole to Mpc-scale jet-driven outflows, and from day-scale variability to duty cycles that can last up to 10^8 years. Shock heating by radio jets is known to play an important role in cluster physics and galaxy evolution. In recent years, we have finally been able to build statistical samples of sources for which the jet feedback takes place on host galaxy scales. However, detailed studies of the physics of jet-driven shocks in this population remain challenging.

We examine X-ray, radio, and optical data of 3C 15, a nearby radio galaxy with a morphology that is in-between that of an FRI and an FRII - showing a single hotspot, a one-sided jet, and a bright radio core - and whose accretion rate, X-ray luminosity, and jet power are similarly intermediate. We study the emission from the core, the jet, and the lobes, and find evidence of jet-driven shells of shocked gas moving supersonically through the host galaxy's halo and into a sparse galaxy group environment. We constrain the age of the lobes, and discuss the effects that a strong shock may have on the host galaxy, as well as its possible impact on the long-term fuelling of the central black hole. The core, traditionally classified as a low-accretion rate AGN, has brightened substantially in recent years, showing signs of radiatively efficient accretion. 3C 15 thus bridges a crucial gap between low-power galaxy-scale jets in sparse environments and the radio galaxy powerhouses carving cavities in dense galaxy clusters, and it could hold key answers on how feedback physics and activity cycles scale between these two populations.

LLAMA: Revealing cold molecular gas structure and dynamics in nearby luminous AGN and matched inactive galaxies with ALMA

Authors

Daniel Hill (1)

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Abstract

Active Galactic Nuclei (AGN) shape the galactic environment in which they reside. Early cross-population studies of the role of AGN feedback have suffered a fundamental limitation: intrinsic differences between AGN hosts and inactive galaxies that are unrelated to the accretion. The Local Luminous AGN with Matched Analogues (LLAMA) survey was designed specifically to address this. LLAMA targets the 20 most luminous southern X-ray AGN within 50 Mpc, each matched with at least one carefully-controlled inactive galaxy. In this talk I will present new high-resolution molecular gas maps from ALMA, comparing the structure and dynamics of the cold, star-forming gas in the central 100s of pcs of the LLAMA galaxies, through surface density profiles, clumpiness, and asymmetry. We report on a negative trend in central (50pc) gas density against AGN power, consistent with recent cyclical models of feedback-regulated supermassive black hole growth. Our results help constrain the physical and temporal scales over which individual episodes of active accretion are moderated by the inflow of gas to the nucleus.

Too Heavy to Lift? Molecular Filaments and AGN-Driven Uplift in Abell 1795

Authors

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Abstract

This talk will present new ALMA 13CO(2-1) observations of the central galaxy in the cool-core cluster Abell 1795, probing the origin of its extended molecular filaments. These 5-7kpc structures are closely associated with radio bubbles inflated by AGN jets, and exhibit smooth velocity gradients consistent with uplifted, entrained flows. We detect 13CO emission in the northern filament and determine a molecular gas mass of $(1.0 \pm 0.5) \times 10^9$ $M_\odot$, implying a CO-to-H2 conversion factor of ~0.6 times the Milky way value. The inferred filament mass is substantial and exceeds the maximum buoyant lifting force of a single bubble by a factor of ~5. We suggest that the molecular gas must have been entrained by multiple generations of radio bubbles or formed in-situ through the condensation of uplifted, low-entropy, hot gas. These results highlight the complex, multi-scale nature of AGN-driven outflows, linking jet-inflated bubbles to cold gas formation and uplift, helping to shed some light on how AGN feedback couples to the surrounding galaxy.

How different AGN accretion modes drive outflows: insights from LoTSS and DESI

Authors

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Abstract

A key ingredient in models of galaxy evolution is AGN-driven gas outflows, which regulate star formation. While much progress has been made since the emergence of large-scale surveys more than two decades ago, the physical mechanisms that accelerate AGN-driven outflows remain unclear; this situation is further complicated by different AGN accretion regimes having different forms of dominant energetic output. Proposed outflow drivers include direct radiation pressure from the accretion disk and shocks powered by jets or disk winds. To address this, we applied a probabilistic classification scheme to 144 MHz radio observations from the LOFAR Two-metre Sky Survey (LoTSS) and optical spectroscopy from the DESI survey. This produced a sample of tens of thousands of high-confidence AGN, classified into HERGs, LERGs, and radio-quiet AGN - the largest of its kind. This has permitted us to statistically determine the roles of optical luminosity (correlated with radiation pressure) and radio luminosity (tracing shocks and jets) simultaneously in driving warm (T>10,000K), ionised outflows across different accretion regimes.

For radiatively-efficient systems (HERGs and RQAGN), we recover the result that the highest outflow velocities are found at intermediate radio luminosities. Crucially, we also discover that this enhancement occurs only at high optical luminosities, within which optical luminosity correlates positively with outflow velocity. In contrast, while LERGs (radiatively-inefficient AGN) present a similar fraction of high-velocity systems as the other classifications, there are no clear relations between outflow velocity and luminosity - this indicates that a key difference between accretion modes is not their ability to drive high-velocity outflows, but the luminosity regime in which these outflows occur. In this talk, I will discuss the implications of our results and describe possible scenarios which could explain our findings, including a combination of both low-power jets and radiation pressure being important for driving the highest-velocity outflows across different accretion modes.

The relationship between radio-loud AGN morphology and host-galaxy properties in LoTSS DR2

Authors

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Abstract

Active galactic nuclei (AGN) influence their host galaxies through a variety of feedback mechanisms, including relativistic jets. Extended radio loud AGN (RLAGN) provide a clear view of jet driven feedback, yet the physical origin of the two predominant morphological classes (FRIs and FRIIs) remains unresolved. FRIIs are thought to maintain relativistic speeds throughout the full length of their jets before terminating in hotspots, while FRIs decelerate on kiloparsec scales due to mass loading from entrainment. Understanding this dichotomy is therefore essential for studying the energetical impact of jets on multiple scales. Early studies found that radio morphology is closely linked to radio luminosity, but newer surveys such as LOFAR have shown that luminosity alone cannot explain the FRI/FRII divide. In this talk, I will present a new semi automated method for classifying RLAGN morphology, applied to LoTSS DR2 to construct the largest publicly available catalogue of FRI and FRII sources to date. Using this sample of 3,590 FRIIs and 2,354 FRIs (at $z \leq 0.8$), we re examine the physical drivers behind the FR divide by connecting jet and host galaxy properties. For sources near the FR divide, we find evidence to support the role of inner environment in determining jet disruption.

Galaxy-Scale Jets in the LOFAR-VLBI Deep Fields: Probing AGN Feedback on Galactic Scales

Authors

Giulia Lusetti (1), Judith Croston (1)

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Abstract

While the impact of large-scale radio jets is well established and explored, the role of small-scale jets, confined within or just beyond the host galaxy ($\lesssim 100$ kpc), remains poorly constrained. These galaxy-scale jets (GSJ) are expected to directly interact with the interstellar medium, making them a key component in understanding AGN feedback on galactic scales.
In this talk, I present the first systematic study of GSJ based on LOFAR-VLBI observations of the Lockman Hole and ELAIS-N1 Deep Fields. These data combine sub-arcsecond (0.3-1.8 arcsec) and standard-resolution (6 arcsec from LoTSS) imaging at 145 MHz, enabling the identification of radio jets on scales down to ~10-20 kpc across a wide redshift range ($0 < z < 3$). By exploiting the multi-resolution nature of these datasets, we construct a new catalogue of about 1000 GSJ sources with linear size $<100 ~kpc$ - the regime where sources become unresolved in standard 6" LOFAR images -, including a prime subsample of about 500 objects with with linear size $\rm <50 ~kpc$. This was done via a careful work of multi -resolution -frequency crossmatching, combined with automated size and flux measurements with visual morphological classification, which I will briefly describe during the first part of this talk. I will also reflect on the main successes and critical aspects of this process, highlighting lessons learned that will help future studies with next-generation facilities such as SKA.
This sample fills a critical observational gap between compact radio sources and classical large-scale radio galaxies, providing a unique opportunity to study jet-driven feedback where it first couples to the host galaxy. To this end, in the second part, I will present the first demographic trends of this population, including size and luminosity distributions, and their dependence on host galaxy properties such as stellar mass, morphology, and AGN accretion mode. In particular, I will explore whether GSJ preferentially reside in different host environments (e.g. spiral vs elliptical galaxies, HERG vs LERG systems), and how these trends evolve via redshift-binned population studies, up to the epoch of cosmic noon $z\sim 2$ and beyond, the most active phase of galaxy formation. Interestingly, the above mentioned visual inspection allowed us to identify a population of galaxy-scale jets in sources classified as star-forming galaxies, suggesting that jet activity may be more widespread across galaxy types than traditionally assumed.

Towards constraining AGN feedback from the gas distribution in haloes

Authors

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Abstract

AGN feedback can influence galaxy evolution across a wide range of scales, from the immediate surroundings of the accreting black hole to the circumgalactic and intragroup media, through channels including jets, winds, and radiative heating. Understanding how these mechanisms shape the distribution of gas around galaxies, groups, and clusters remains a central challenge for galaxy formation, and is essential for connecting black hole growth to observable baryonic structures across cosmic time. Using state-of-the-art cosmological hydrodynamical simulations, including Simba, IllustrisTNG, and EAGLE, I investigate how different feedback models affect the radial distribution of gas around haloes over the mass range 10^10.5-10^15 M_Sun and redshift interval 0<z<4, and how this structure relates to global halo and galaxy properties.

A physically interpretable machine-learning framework shows that radial gas density profiles can be predicted with high accuracy from a small set of global quantities, and identifies the total halo mass and the gas mass of the central galaxy as the dominant drivers of halo gas structure, while stellar and black hole properties play smaller, model-dependent roles. This provides a general framework for understanding how feedback shapes halo gas across simulation models. Within Simba, where different stellar and AGN feedback variants can be compared directly, the gas density profiles are well described by power laws over a wide range of masses and redshifts, with slope and amplitude only weakly dependent on redshift at fixed halo mass. AGN jet feedback leaves a distinctive imprint in the most massive systems: in groups and clusters, the gas density declines more gradually with radius, reflecting an enhanced hot circumgalactic medium.

Together, these results provide a coherent route for linking feedback physics, galaxy properties, and the multi-phase gas distribution around haloes. They are part of a broader effort to constrain AGN feedback models by tracing different gas phases around galaxies, groups, and clusters across redshift, and by connecting simulation predictions to current multi-wavelength observations from facilities such as ALMA, JWST, and LOFAR, as well as to future constraints from SKA and Athena.

Connecting accretion to jet activity across AGN populations with MIGHTEE and LoTSS

Authors

Charlotte Jackson (1)

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Abstract

It is still a mystery why a fraction of AGN are able to launch and sustain powerful radio jets, whilst others, even at similar luminosities and accretion powers, are not. We confront this question, and investigate the conditions associated with jet launching in a sample of 13k MIGHTEE-detected sources in the COSMOS field, where there is a wealth of multi-wavelength ancillary observations.

We use detailed FUV-FIR spectral energy distribution fitting to derive both host-galaxy and AGN properties, including stellar mass, star formation rate, and disc accretion rate. These measurements are supplemented with deep 1.4 GHz MIGHTEE observations, and together are used within a new Bayesian hierarchical framework for defining the star formation-radio continuum correlation. This allows us to infer any dependence on redshift and stellar mass, while also identifying a probabilistic population of jetted AGN, accounting for observational and modelling-based uncertainty.

Using this framework, we examine how the prevalence of radio jets depends on host-galaxy and AGN properties, focusing in particular on the evolution of the jet fraction as a function of Eddington ratio, and the coupling of this to other physical characteristics. We compare these results to those from SDSS quasars observed with LOFAR, testing whether a common ground in jet launching can be found across AGN mass scales.

Mapping multi-phase feedback in the most extreme population of obscured AGN

Authors

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Abstract

Our understanding of galaxy evolution is underpinned by the interactions between SMBHs and their hosts in the form of nuclear feedback (outflows, inflows, jets etc.). The bulk of this feedback occurs when the nucleus is dust-obscured, yet, despite current evolutionary models almost unanimously predicting a dust-obscured nuclear phase, we lack the multi-wavelength observational framework to test these predictions.
Compact obscured nuclei (CONs) represent a population of the most deeply embedded active galactic nuclei (AGN), thought to exist in 20-40% of local (ultra-) luminous IR galaxies (ULIRGs). All known CONs have been shown to host outflows, winds and/or jets, with most also showing evidence for inflows. This prevalence of out/inflows in CONs points to them being in a prolific, yet poorly understood, feedback phase, making them ideal laboratories in which to study the effects of nuclear feedback in galaxies. However, their extreme nuclear column densities ($N_{\rm{H}} > 10^{25}$ cm^{-2}) erase many of the traditional AGN signatures meaning that the dominant source of their IR emission and the mechanism(s) driving their outflows, remains unconfirmed.
In this session, I will present a new study on the local CON Zw049.057. By combining wide-field IFU data from MUSE, and ALMA interferometry, I will reveal the multi-phase feedback processes happening on different scales in the galaxy. Specifically, these observations show the presence of a spectacular collimated molecular outflow (CMO) and inflowing gas on scales $\sim$100 pc, and a clumpy ionised gas outflow on kpc scales in the galaxy. I will discuss how these features are linked to each other and to a previously identified radio jet. I will use the energetics of these features to place constrains on the mechanisms that drive CON outflows and the impact this has on our understanding of CONs in the context of SMBH-galaxy coevolution.

A Red Geyser at Cosmic Noon

Authors

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Abstract

Star-formation quenching is one of the main processes driving galaxy evolution, but is still poorly understood. By Cosmic Noon ($z\sim2$), a significant fraction of massive galaxies has already stopped forming new stars: observing recently-quenched systems at this redshift is crucial to investigate the main quenching mechanisms responsible for the passive evolution of the most massive galaxies in our Universe. \\
We analyze NIRSpec IFU spectroscopy for a small sample of 5 rare, gravitationally-lensed massive quiescent galaxies at $2.1 < z<2.6$, all recently quenched (<1 Gyr). By studying emission line ratios diagnostics we investigate the ionized gas physical conditions and the underlying ionization sources. We find widespread presence of low-level AGN activity throughout the sample and no hints of residual star-formation; possibly linking the quenching of massive galaxies at Cosmic Noon to AGN-driven feedback. For one galaxy in the sample, we find evidence of galaxy-wide powerful outflows in the ionized phase. Thanks to the combined lensed magnification and NIRSpec IFU's angular resolution, we are able to build spatially resolved maps of ionization properties and gas kinematics of this system to deeper investigate the origin of the observed emission. We use the 3D gas kinematics modeling code \texttt{MOKA3D} (Marconcini et al. 2023) to constrain the geometry and physical properties of ionized gas winds. We find that observations are consistent with an outflowing biconical wind model driven by the low-luminosity AGN hosted at the center of the galaxy; with similar properties to what is observed in so-called "Red Geysers" quiescent galaxies in the Local Universe. This evidence suggests that low-level AGN activity capable of suppressing star formation through heating of ambient gas by ionized winds is already in place in the most massive galaxies by Cosmic Noon.

Linking accretion and jet activity in AGN across cosmic history with WEAVE-LOFAR and X-ray observations

Authors

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Abstract

Feedback from accreting black holes (or Active Galactic Nuclei; AGN) is predicted to play a crucial role in shaping the growth of galaxies. In particular, AGN that produce extended relativistic jets visible in the radio are believed to be key to shutting down star-formation in the most massive galaxies. However, the details of exactly how the jet activity observed in radio AGN (on kilo- to Megaparsec scales) is linked to the underlying accretion (on sub-parsec scales) have remained elusive, along with the details of how those radio jets impact their host galaxies.

In this talk, I will show how host-galaxy properties and black hole masses of ~1800 type-I AGN can be derived using optical spectroscopy from the Dark Energy Spectroscopic Instrument (DESI) DR1 survey of radio-selected sources from the second data release of LOFAR Two-metre Sky Survey (LoTSS DR2). This methodology will then be applied to the upcoming UK-led spectroscopic survey WEAVE–LOFAR, which will provide more than one million spectra of radio-selected sources. Combined with high-sensitivity, high-resolution LOFAR observations, these data will allow us to connect jet properties and activity to the host-galaxy environment, revealing the role of jets in galaxy evolution.

Additionally, X-ray observations probing supermassive black hole accretion in unprecedented samples of AGN across cosmic history will allow us to establish the connection between jets and the accretion disks, thereby building a more complete observational picture of AGN and their host galaxies.

Observational signatures of AGN outflows from the radio to the optical

Authors

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Abstract

Multi-wavelength observations show that bright AGN drive large-scale outflows. How these outflows interact with multiphase gas and impact galaxy evolution on cosmological timescales is still not understood. In this talk, I will discuss how we can connect theoretical models of AGN outflows to observable signatures, focusing on optical emission lines and radio emission. I will present results from recent high-resolution hydrodynamical simulations with AREPO that follow energy-driven AGN outflows expanding through a realistic multiphase interstellar medium. By resolving the cool gas phase (T<10^4.5 K) and its interaction with the outflow, the simulations allow predictions for commonly used optical tracers, including [OIII] emission lines, and show how these tracers relate to the total mass, momentum, and energy of the outflow. I will also present new magnetohydrodynamic (MHD) simulations including cosmic-ray transport physics to model relativistic particles accelerated in shocks generated by these outflows. This approach is useful to find the dominant source of radio-emissions in AGN. Understanding the exact physical mechanisms behind these outflows has important implications for constraining AGN impact on host galaxies, as well as their role in galaxy evolution and the regulation of star formation.

Posters

Extragalactic radio jets on sub-kpc scales

Authors

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Abstract

Relativistic plasma jets are conduits through which energy, momentum, and angular momentum are transported from the centre of active galactic nuclei (AGNs) to vast distances, extending from sub-parsec to megaparsec scale structures such as hotspots and lobes where they terminate, influencing the so-called AGN feedback processes. Although sufficient energy input is available from jets, both how feedback is regulated and the processes required to heat the intergalactic medium remains open. To resolve them, we need to map jet outflows and their interaction with the environment. Using high-resolution and high-sensitivity radio data from the e-MERLIN jets legacy programme, we attempt the highest fidelity imaging to-date of the inner jet structure in the radio quasar 3C 273. The goal is to resolve the jet structures where they first brighten and place constraints on the dynamics and kinematics of the radio jet within the vicinity of the AGN. In this paper, I will present preliminary results from our study and discuss future work on spectral and polarimetric analysis on 3C 273 and other sources of similar type.

AGN wings: Exploring the X-ray Emission Mechanism of Cross-Shaped Radio Galaxies

Authors

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Abstract

Radio jets from Active Galactic Nuclei (AGN) provide large scale feedback. Jet-related X-ray emission can reveal clues about the history of AGN-environment co-evolution through shocks and cavities. X-shaped radio galaxies (XRGs) provide a powerful probe of how AGN feedback redistributes energy away from the primary jet axis over multiple activity cycles. We report on a newly discovered X-ray eastern wing detected in the FRII quasar 3CR 14 (z=1.5) which aligns only with low frequency radio (144 MHz) emission. New sub-arcsecond LOFAR HBA observations shows symmetric off-axis emission giving this quasar an X-shaped morphology, unseen at higher frequencies. The radio and X-ray energetics depart from equipartition by a factor of >7 (roughly double typically observed factors) indicating inverse-Compton models may require additional energy injection. In the northern jet, an X-ray hotspot aligned with a spectrally steeper secondary radio hotspot shows either a historical jet terminus or jet deflection. New high resolution LOFAR observations of quasar 3CR 34 (z=0.7) also show X-ray aligned radio wings, only observed at 144 MHz yet appearing sufficiently far from equipartition (a factor of nearly 7) that inverse Compton process cannot conclusively reproduce the observed X-ray emission.

Spectropolarimetric analysis of a sample of powerful jets in nearby galaxy groups with MeerKAT

Authors
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Abstract
Determining the properties of the galaxy groups at high redshift can provide important constraints for the formation path of low-redshift galaxy clusters. However, measurements of the hot intra-group medium (IGrM) and the magnetic field strength in groups at $z>1$ are challenging with current instrumentation. One solution is to constrain them with the Faraday rotation measures (RM) of the extended radio emission from their central active galactic nuclei (AGN). In this work, we select seven nearby powerful radio sources (PKS 0038-09, PKS 0213-13, PKS 0349-27, PKS 0945+07, PKS 1559+02, PKS 2356-61, and 3C 98), forming a representative sample of galaxy groups as analogues to high-redshift objects. Utilizing the spectropolarimetric capabilities of the MeerKAT radio telescope, we investigate the correlation between their RM properties and the existing X-ray measurements of IGrM density and magnetic field strength. We calibrated the deep MeerKAT L-band data and obtained the Faraday rotation measures of the sample using the RM synthesis technique. We analyze the morphologies, spectral indices, depolarizations, magnetic field structures, and RM structures (scatter and structure function) of the sources. All our sources show typical FRII morphology. Low-brightness extensions of the wing-shaped structures are newly detected in several sources owing to the improved sensitivity. L-band spectral index maps suggest that the wings in most objects are likely a part of the backflow, while the north-south wings of PKS 0349-27 are possibly from a previous episode of AGN activity. We find significant differences in and depolarization in the 2 lobes of PKS 0038+09, PKS 0945+07, and PKS 2356-61, likely a signature of the Laing-Garrington effect. Large depolarization is detected at smaller radii from the center of the groups, although its origin is likely complicated. The magnetic field is aligned with the boundary of the lobes and wings, and perpendicular to the radio jet, as found by existing studies. The RM structure functions are computed in the well-resolved objects. We also studied the correlation between the RM scatter of the whole source with $\langle n_e\rangle$ and B in the cocoon. This work tests the concept of constraining n_e and B properties in galaxy groups with RM measurements of a single extended source. More simulation and modeling work is needed for a better interpretation of the results.

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.

Push and pull – Studying the interplay between AGN and starforming gas

Authors

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Abstract

Radio galaxies host some of the most energetic AGN in the Universe. They drive powerful jets and winds that can significantly impact their host galaxies' star formation and gas content. Neutral hydrogen (HI) is the fuel for star formation and, due to its extended distribution beyond the stellar disc, bears strong signatures of the galaxy's environment. It therefore offers an ideal window into the impact of AGN feedback on the cold gas reservoir, which remains poorly understood. We address this using the SIMBA cosmological hydrodynamic simulation, which has already been shown to reproduce the MIGHTEE radio galaxy survey population well. We identify high- and low-excitation radio galaxies (HERGs and LERGs) in SIMBA at z = 0-1, separating centrals and satellites, and characterise their global properties. Mock HI spectral-line cubes are constructed and analysed to investigate the gas' properties, and asymmetries, providing observational analogues for comparison with MeerKAT MIGHTEE-HI data. We further explore how HI content and gas asymmetry vary across different AGN feedback modes in SIMBA.

Developing next-generation AGN feedback models for cosmological simulations

Authors

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Abstract

With a new generation of telescopes and advances in observational capability comes the need for a new generation of simulations. AGN feedback has been clearly established as a key component of modern cosmological simulations in order to produce a realistic population of galaxies. However, how exactly AGN feedback operates is still an active area of debate, with a range of simulation suites adopting a variety of models and parameterisations to match observations. Recent X-ray observations with eROSITA, as well as Sunyaev-Zel'dovich observations, place new (and potentially conflicting constraints) on group and cluster gas properties and distributions. We employ the latest version of the magnetohydrodynamics code AREPO to perform a suite of new simulations constraining AGN feedback models to match these latest observations. Building on the previous FABLE suite, we now include magnetic fields and recalibrated models to build a library of high-resolution galaxy groups and clusters as a basis for future simulations implementing advanced spin-driven jet-mode feedback models. I will present the current status of this project, including how different feedback modes and models impact the evolution of galaxy groups and clusters, as well as how these compare to the most recent observational constraints for these systems.