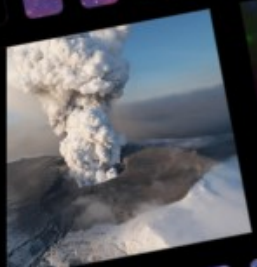
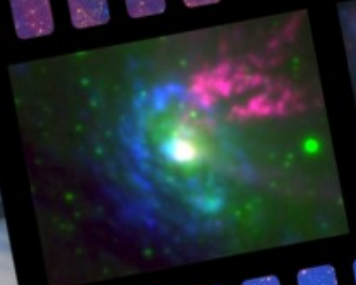
★ ~~10th~~ 12th ANNIVERSARY SPECIAL ★

WHAT DRIVES THE GROWTH OF... BLACK HOLES?

Iceland, 26–30 Sep 2022


A DECADE OF REFLECTION

Durham University

DARTMOUTH

MNU MATARIKI NETWORK OF UNIVERSITIES

dartgo.org/growthofBHs

Contents

What Drives the Growth of Black Holes: A Decade of Reflection

Dartmouth-Durham Extragalactic Workshop,

Reykjavík Iceland, 26 - 30 September 2022

https://astro.dur.ac.uk/~xswt42/Growth_of_Black_Holes/

Massive black holes are at once exotic and yet ubiquitous, residing at the centres of massive galaxies in the local Universe. Recent years have seen remarkable advances in our understanding of how these black holes formed and grew over cosmic time, during which they are revealed as Active Galactic Nuclei (AGN).

The focus of this workshop is to review our understanding of what drives the growth of black holes, to reflect on the progress made in the last decade, and to look towards expected future advances enabled by conceptual and technological improvements.

The scientific sessions of the conference are broadly the same as our first workshop in 2010 on "What drives the growth of black holes?", allowing for a direct comparison of progress made in the last decade:

- How does the gas accrete onto black holes, from kpc to sub-pc scales?
- What properties of the host galaxies or larger-scale environment affect black-hole growth?
- What fuels the rapid growth of the most massive (and also the first) black holes?
- What impact do AGN winds/jets/outflows have on the black-hole fueling and star formation?

Conference Format

The talks and posters have been organised into four main sessions to address each of the four questions listed above. After the talks for each session there will be a discussion session. Each discussion session will begin with 1 min spot-light/poster talks, followed by a chaired discussion reflecting upon the presented talks, posters, and registration questions.

Scientific Organising Committee

David Alexander • Ryan Hickox • James Aird • Francoise Combes • Sara Ellison • Eilat Glikman • Chris Harrison • Cristina Ramos Almeida • Benny Trakhtenbrot • Marta Volonteri • Dominika Wylezalek • Nadia Zakamska

Local Organising Committee

David Alexander • Ryan Hickox • Leah Morabito • George Lansbury • Tonima Ananna • Carolina Andonie • Alice Eltvedt • Emmy Escott • Vicky Fawcett • Brivael Laloux • James Petley • Grayson Petter • Stephanie Podjed • Kelly Whalen

Venue and Locations

Oral presentations	Kaldalón auditorium, Harpa
Posters, coffee & registration	Outside Kaldalón auditorium, Harpa
Sunday evening reception	Björtuloft reception hall, Harpa at 6pm
Wednesday excursion	Depart outside Harpa at 9am, return about 7pm
Thursday conference dinner	Gamla Bíó (old cinema), Reykjavik at 7pm

Presentation Information

Talks – Retrospective/review talks [R] are 35+5 minutes and contributed talks are 12+3 minutes. Each session will have spot-light talks/posters (1 min each) which will run prior to the 45-60 min discussion to end each session. All speakers must provide us with their talk on a thumb drive in advance of their presentation to avoid any technical issues – we will not be swapping between laptop computers. We recommend no more than 1 slide for each spot-light talk which must be provided in PDF format prior to the start of the conference.

Posters – Posters are displayed outside the Kaldalón auditorium in the area set aside for registration and the coffee breaks. In-person posters categorised in sessions 1–2 are displayed on Monday–Tuesday while in-person posters categorised in sessions 3–4 are displayed on Thursday–Friday. The poster boards allow up to standard-sized posters (A0 or 36 x 48 inches); because of limited space, standard-size posters must be orientated vertically. All posters (both remote and in person) are also available on line throughout the duration of the conference.

All poster presenters have the option to give a 1 min spot-light talk on their poster; see above for instructions.

Twitter

We encourage you to Tweet throughout the conference using #BHGrowth2022 .
Our account is: @BHGrowthDecade.

Slack

We encourage you to use the Slack workspace throughout the conference to connect with colleagues, ask questions, discussions, keep informed about schedules and timing etc.
The Slack workspace is: http://bhgrowth2022.slack.com/

What Drives the Growth of Black Holes?: A Decade of Reflection

Sunday 25th September 2022

18.00 **Evening Reception: Björtuloft reception hall, Harpa**

Conference Programme

Monday 26th September 2022

8.00 **Registration**

9.00 **Welcome and Scientific Motivation of the Conference**

How does the gas accrete onto black holes, from kpc to sub-pc scales?

9.20 **Session 1, block 1** – *Chair: Ryan Hickox*

Françoise Combes [R]	How does the monster take its meals?
Angelo Ricarte	Current results on Sgr A* and M87, and the future of the EHT
Violeta Gámez Rosas	MATISSE results on NGC 1068: on the dust at pc scales from the AGN

10.40 **Coffee Break and Poster Session**

11.20 **Session 1, block 2** – *Chair: David Alexander*

Daniel Anglés-Alcázar	Cosmological hyper-refinement simulations of AGN fueling and feedback
Pierrick Verwilghen	Simulating the building and evolution of central gas reservoirs: towards black hole fuelling
Lindsey Byrne	Stellar-Feedback Regulated Black Hole Growth: Connecting the Inner Regions of Galaxies to the Physics of the Circumgalactic Medium
Takuma Izumi	Multiphase dynamical gas fountain that replaces the classical black hole obscuration
Timothy Davis	Getting wise to the role of cold molecular gas in AGN fueling

12.45 **Lunch**

14.15 **Session 1, block 3** – *Chair: Francesco Shankar*

Natalia Osorio Clavijo	On the study of torus disappearance in LLAGN as seen through X-rays
Zsofi Igo	An X-ray and Radio View of the different modes of AGN Accretion and Feedback with eROSITA and LOFAR
Filippo Mannucci	Uncovering the missing population of dual AGNs with Gaia
	Spot-light talks (Session 1)

15.40 **Coffee Break and Poster Session**

16.20 **Session 1, block 4**

	Discussion (Chairs: Françoise Combes; Cristina Ramos-Almeida)
	Spot-light talks (Session 2)

17:50 **End**

Conference Programme

Tuesday 27th September 2022

8.00 **Registration**

What properties of the host galaxies or larger-scale environment affect black-hole growth?

9.00 **Session 2, block 1** – *Chair: Mariana Lazarova*

James Aird [R]	Black hole growth across the population of galaxies and their large-scale environments
Ena Choi	The Origins of Gas Accreted by Supermassive Black Holes: How Do Supermassive Black Holes Get Their Gas?
Keir Birchall	The Incidence of X-ray selected AGN in the nearby Universe
Meredith Powell	Constraining the SMBH-halo connection in the local universe
Giorgia Peluso	Exploring the AGN-ram pressure stripping connection in local clusters

10.40 **Coffee Break and Poster Session**

11.20 **Session 2, block 2** – *Chair: Yoshihiro Ueda*

Robert Bickley	A multi-wavelength census of merger-fueled SMBH accretion
Sean Dougherty	Enhanced AGN activity for close galaxy pairs at z=0.5-3
Carolin Villforth	Do mergers matter? Luminosity, obscuration and the triggering of AGN
Sabrina Stierwalt	Determining the AGN Fraction in Dwarf Galaxy Mergers
Ragadeepika Pucha	Black Hole Seeds in Dwarf Galaxies: Early Results from DESI

12.45 **Lunch**

14.15 **Session 2, block 3** – *Chair: Andrea Comastri*

Jiri Svoboda	Are black-hole accretion states similar across the mass scale?
Ivan Delvecchio	Linking radio AGN activity to galaxy growth: a super-linear "radio-AGN main sequence"
Rohit Kondapally	Discovery of a dominant new population of jet-mode AGN at high redshift
Dale Kocevski	A First Look at the Resolved Host Properties of AGN at $3 < z < 5$ with JWST
Hamsa Padmanabhan	Fuelling the first black holes: contribution of tidal disruption events

15.40 **Coffee Break and Poster Session**

16.20 **Session 2, block 4**

Santiago García-Burillo	Anatomy of molecular dusty tori and nuclear outflows in nearby AGNs
Almudena Alonso-Herrero	Extended warm dust nuclear emission in nearby Seyfert galaxies
	Discussion (Chairs: James Aird; Carolin Villforth)

17.50 **End**

Conference Programme

Wednesday 28th September 2022

Free day for organised excursion (South Shore Adventure tour) or other activities. Note South Shore Adventure tour departs 9am from Harpa, returning about 7pm.

Conference Programme

Thursday 29th September 2022

What fuels the rapid growth of the most massive (and also the first) black holes?

9.00	**Session 3, block 1** – *Chair: Leah Morabito*
Melanie Habouzit [R]	The assembly of the most massive black holes
Satoshi Yamada	Comprehensive Multiwavelength Studies of Local U/LIRGs observed with NuSTAR and/or Swift/BAT
Tanio Diaz Santos	The Feeding Habits of SMBHs in Extremely Luminous Obscured Quasars at Cosmic Noon and Beyond
Hannah Stacey	Dusty quasars eject star-forming gas from galaxies at cosmic noon
Yoshiki Toba	eROSITA and WISE view of dust-obscured AGN at z<4
10.40	**Coffee Break and Poster Session**
11.20	**Session 3, block 2** – *Chair: Manda Banerji*
Victoria Fawcett	Why is colour special? Identifying fundamental differences between blue and red quasars
Grayson Petter & Kelly Whalen	Physical Models for the Clustering of Obscured and Unobscured Quasars
Gabor Worseck	Dating Individual Quasars with the He II Proximity Effect
Marco Mignoli	Web of the giant: First spectroscopic confirmation of a large-scale structure around a z>6 super-massive Black Hole
12.30	**Lunch**
14.00	**Session 3, block 3** – *Chair: Gordon Richards*
Jan-Torge Schindler	Supermassive Black Hole Growth in the Reionization Era: Evolution of Quasar Properties and Demographics
Fabio Di Mascia	AGN imprints on the IR emission of the first galaxies
Amy Barger	Are the First Black Holes More Easily Discovered in the Submillimeter than the NIR?
Nico Cappelluti	The Early Universe in a PBH-Lambda-CDM Cosmology: How a simple solution might solve several difficult problems
15.10	**Coffee Break and Poster Session**
15.40	**Session 3, block 4**
	Spot-light talks (Session 3)
	Discussion (Chairs: Eliat Glikman; Benny Trakhtenbrot; Marta Volonteri)
17.00	**End**
19.00	**Conference dinner: Gamla bíó (old cinema) restaurant**
	Presentation with Roger Blandford

Conference Programme

Friday 30th September 2022

What impact do AGN winds/jets/outflows have on the black-hole fueling and star formation?

9.00 **Session 4, block 1** – *Chair: Karen Leighly*

Tiago Costa [R]	The many roads to AGN feedback
Dominika Wylezalek	AGN feedback signatures from small to large scales
Marko Stalevski	Dissecting the obscuration and outflow of AGN in Circinus galaxy
Erin Hicks	The Keck OSIRIS Nearby AGN Survey: Tracing Fueling and Feedback in local AGN
Travis Fischer	Let's talk about jets: Analysing Extranuclear Radio Sources in NGC1068

10.40 **Coffee Break and Poster Session**

11.20 **Session 4, block 2** – *Chair: Marcella Brusa*

Stephanie Juneau	Elucidating the impact of galaxy substructure on black hole growth and AGN feedback
Michael Calzadilla	Testing the Limits of AGN Feedback in the Most Rapidly Star Forming Brightest Cluster Galaxies
James Petley	How can we determine the source of the enhanced radio detection fraction of quasars with strong winds?
Caroline Bertemes	MASCOT: Gas-phase metallicity gradients as a probe of outflows, star formation and inflows as active galaxies transition to the red cloud
Jan Scholtz	Detection of massive molecular and dust reservoirs around $z \sim 2$ extremely red quasars: CGM enrichment by quasar-driven outflows

12.45 **Lunch**

14.15 **Session 4, block 3** – *Chair: Belinda Wilkes*

Cristina Ramos Almeida	The cold molecular gas kinematics of type-2 quasars as seen by ALMA
Chiara Circosta	The impact of active galactic nuclei on the molecular gas reservoir of their host galaxies at Cosmic Noon
Darshan Kakkad	The impact of AGN outflows on star formation at cosmic noon using AO-assisted IFS observations
	Spot-light talks (Session 4)

15.40 **Coffee Break and Poster Session**

16.20	**Session 4, block 4**
Samuel Ruthven Ward	Finding AGN in gas-rich, star-forming galaxies does not rule out current AGN feedback models
Jong-Hak Woo	The correlation of AGN outflows with SFR suggests delayed AGN feedback
	Discussion (Chairs: Chris Harrison; Dominika Wylezalek; Nadia Zakamska)
	Conference wrap up
18.00	**End of conference**

Poster Programme

Posters are displayed throughout the workshop in the exhibition space outside the Kaldalón auditorium. The numbers given below refer to the board on which each poster is displayed. Posters for Session 1 and 2 will be displayed Monday and Tuesday and are labeled with 'A#' for in-person and 'R-A#' for virtual posters. Posters for Session 3 and 4 will be displayed Thursday and Friday and are labeled with 'B#' for in-person and 'R-B#' for virtual.

Session 1 posters:

Ananna	A1	Studying the Structure of the Obscuring Torus using Eddington Ratio
Avirett-Mackenzie	A2	The role of galaxy mergers in fuelling active galactic nuclei
Balokovic	A3	Broadband X-ray Spectroscopy as a Probe of AGN Obscuring Structures
Burkert	A4	Watching a Little Gas Cloud G2 orbiting the Galactic Supermassive Black Hole
Eltvedt	A5	The dependence of QSO accretion disk size on black hole mass
Green	A6	AGN variability in the Ultra Deep Survey
Gupta	A7	Multi-Wavelength Properties of Local Active Galactic Nuclei
Hauschild Roier	A8	Gas inflows in the polar ring of NGC 4111: the birth of an AGN
Hinrichs	A9	Observing Intermediate-Peaked Blazars with VERITAS
Isbell	A10	The Dusty Heart of Circinus: Imaging the Circumnuclear Dust in N-band
Iwata	A11	Unveiling the origin of hard X-ray emission of Centaurus A with multi-epoch NuSTAR observations: disk or jet?
Krumpe	A12	Multi-wavelength follow-up of extreme variability in AGN detected with eROSITA
Kynoch	A13	Disc reverberation of a rapidly-growing black hole
Malik	A14	Black holes masses from 'industrial-scale' Reverberation Mapping with OzDES
Nagoshi	A15	Origins of broad line region probed by reverberation mapping and multi-wavelength observation of an extremely variable Changing-State Quasar
Pierce	A16	The importance of galaxy mergers and interactions for triggering radiatively-efficient AGN in the local universe
Podjed	A17	SALT Spectropolarimetry of Blazars
Rankine	A18	Determining the intrinsic relation between X-ray and UV/optical tracers of supermassive black hole growth
Selwood	A19	Consistent Analysis of Type-2 AGN Spectra with QSFit
Tanimoto	A20	NuSTAR Observations of 52 Compton-thick Active Galactic Nucleus Candidates Selected by the Swift/Burst Alert Telescope All-sky Hard X-Ray Survey

Terashima	A21	A New Sample of Soft X-ray Bright AGNs: X-ray spectra and UV to X-ray SEDs
Ward	A22	Progress towards a better understanding of "Changing Look" AGN
Zeltyn	A23	Surveying Changing-State AGNs with SDSS-V
Patel	R-A2	Studying the Variability of Quasars as a function of rest-frame wavelength from the Zwicky Transient Facility
Tartėnas	R-A3	Accretion disc-mediated SMBH feeding in hydrodynamical simulations
Yan	R-A4	Heavily-Obscured AGNs and the Host Galaxies in the XMM-SERVS Fields

Session 2 posters:

Acharya	A24	miniJPAS: The 2D properties of X-Ray AGN host galaxies in 56 colors
Byrne-Mamahit	A25	Post-Merger Galaxies and AGN in the IllustrisTNG Simulation
Delaney	A26	The Extragalactic Serendipitous Swift Survey (ExSeSS): survey definition and measurements of the X-ray number counts
Foord	A27	Searching for Dual AGN: A Unique Flag of Merger-Driven SMBH Growth
Glikman	A28	A Dual QSO at Cosmic Noon
Hviding	A29	The Present and Future of Mid-IR AGN Selection: The Optical Spectroscopic Properties of WISE-Matched AGN
Koss	A30	Massive Black Hole Growth in the Local Universe - the BASS Multi-wavelength Perspective
Laloux	A31	A new Bayesian multi-wavelength approach to constrain physical properties and space density of X-ray AGNs
Lambrides	A32	Major Mergers Do Not Trigger the Majority of Less Luminous AGN at Cosmic Noon
Lanz	A33	Feeding and feedback in Post-starburst galaxies
Lazarova	A34	Mergers Dominate the Host Galaxies of Low-z LoBAL QSOs: Insights from HST
López	A35	SMBH accretion rates distributions using the miniJPAS survey
Morabito	A36	Identifying active galactic nuclei via brightness temperature with sub-arcsecond International LOFAR Telescope observations
Moravec	A37	Exploring the Interplay Between Merging Galaxy Clusters and Radio-AGN out to $z\sim1$
Ni	A38	The relation between black-hole growth and host-galaxy compactness among star-forming galaxies
Pfeifle	A39	Spotted: Dual Broad Line AGNs Identified in Two Minor Galaxy Mergers?

Siudek	A40	AGN in dwarfs: does the environment matters?
Stemo	A41	Observational Evidence for a Transition from Offset to Dual AGN Predominance in Late Stage Mergers
Thomas	A42	Radio Galaxies in the era of the SKA: Predictions from Cosmological Simulations
Trakhtenbrot	A43	Black Hole Mapper in SDSS-V
Uematsu	A44	ALMA Lensing Cluster Survey: Properties of Submillimeter Galaxies Hosting X-ray Detected Active Galactic Nuclei
Zhang	A45	TRINITY: Self-Consistently Modeling the Dark Matter Halo–Galaxy–Supermassive Black Hole Connection from $z = 0$–10
Alfarsy	R-A5	Reverberation mapping quasars with DESI
Boorman	R-A6	Understanding the role of the most obscured black hole growth with NuLANDS
Buchner	R-A7	Population evolution with Chandra, XMM, NuSTAR and now eROSITA: from bright unobscured to faint Compton-thick AGN and back
Muñoz Rodríguez	R-A8	Cosmic evolution of AGN incidence in massive clusters

Session 3 posters:

Alonso Tetilla	B1	Probing the relative roles of evolution, orientation and multi-scale gas distributions in shaping the obscuration of black holes through cosmic time
Andonie	B2	A panchromatic view of IR quasars: excess star-formation and radio emission in the most heavily-obscured systems
Barlow-Halll	B3	Constraints on the X-ray Luminosity Function of AGN at high redshift
Bennett	B4	The impact of growing a giant black hole in the early universe
Choi	B5	The properties of outflows and black-hole fueling in FeLoBAL Quasars
Fernández Aranda	B6	Observing and modelling the gas and dust of the most luminous galaxy known
Leighly	B7	Spectral Synthesis Analysis of Broad Absorption Line Quasars
McLaughlin	B8	Detecting short-lived AGN flares
Onishi	B9	CON-quest: dense molecular gas properties in moderately luminous infrared galaxies
Onorato	B10	Public release of Near-infrared and Optical Spectroscopy of Reionization-era Quasars at z>6.5
Pizzati	B11	How do SMBHs populate halos at the high redshift? Interpreting the observed clustering and abundance of quasars with large-volume cosmological simulations
Sala	B12	ub-grid modelling of supermassive black hole accretion, spin evolution and feedback in hydrodynamical simulations

Tang	B13	An insight of SMBH-host galaxy coevolution through dual quasar systems in Subaru HSC-SSP
Umehata	B14	Growth of galaxies and supermassive black holes in the cosmic web filaments at $z = 3$
Wethers	B15	The MUSE view of the CON NGC4418
Gorski	R-B1	Revealing the Growing Nuclear Structure of IC 860s Compact Obscure Nucleus
Lau	R-B2	Probing the Inner Circumgalactic Medium and Quasar Illumination around the Reddest 'Extremely Red Quasar' (ERQ)
Nesulsan	R-B3	Criticism of the identification of metric-tensor component with mass and a model of stupendously large primordial galactic object
Oogi	R-B4	Field variance forecasts of high redshift AGNs for future surveys with a semi-analytic model
Patil	R-B5	A Study of Heavily Obscured Quasars with Young Radio Jets at z 2
Schleicher	R-B6	Origin of supermassive black holes in massive metal-poor protoclusters
Shi	R-B7	Hyper-Eddington Black Hole Growth in Star-Forming Molecular Clouds and Galactic Nuclei
Vrjarnwannaluk	R-B8	The Obscured Fraction of Quasars at Cosmic Noon
Winkel	R-B9	Tracing the onset of the AGN feeding-feedback cycle in the nearby super-Eddington NLS1 Mrk 1044

Session 4 posters:

Albán-Morales	B16	Mapping ionized gas outflows in multi-wavelength selected AGN from MaNGA
Bessiere	B17	Quantifying the impact of AGN-driven winds on the stellar populations of their host galaxies
Borkar	B18	Feeding AGN in the presence of strong Feedback: The Case Study of Centaurus A
Brusa	B19	Supermassive Black Hole Winds in X-rays
Delaney	B20	n Atlas of AGN Near-IR IFU Datasets: Circumnuclear Molecular, Ionized, and Coronal Gas in Seyfert Galaxies
Ellison	B21	Central molecular gas depletion in AGN host galaxies - a smoking gun for kpc-scale feedback?
Escott	B22	Linking [OIII] outflows in AGN to low-frequency radio emission: new observations with LOFAR
Girdhar	B23	The impact of multi-phase outflows and low power radio jets on the host galaxies of quasars
Lanzuisi	B24	Physics and Energetics of the Ultra Fast Outflow in IRAS F11119+3257
Molyneux	B25	The Impact of AGN on the molecular gas properties of quasar host galaxies

Musiimenta	B26	Quasars in the feedback phase: a new discovery space opened by eROSITA
Odaka	B27	Unveiling accretion disc winds from supermassive black holes with Monte Carlo X-ray radiative transfer modelling
Ogawa	B28	Warm Absorbers in the Radiation-driven Fountain Model of Low-mass Active Galactic Nuclei
Randall	B29	The Role of AGN Feedback in Regulating the Growth of SMBHs
Richards	B30	AGN Winds as Probed by Emission Lines, Absorption Features, X-rays, IR, and Radio
Rojas	B31	The AGN-galaxy interplay through spectral modeling and multiphase outflows
Wang	B32	Mapping intrinsic Ly-alpha halos of high-redshift AGN with MUSE
Wilkes	B33	Do Radio Jets Trigger Star Formation in High-redshift Radio Galaxies?
Ayubinia	R-B10	The Correlation of Outflow Kinematics with Radio Emission
Midooka	R-B11	Discovery of the radiatively-driven clumpy absorbers in the NLSy1 IRAS 13224-3809
Rodríguez-Ardila	R-B12	The kinetic feedback channel traced by the coronal gas in radio-weak Active Galactic Nuclei
Valentini	R-B13	Impact of AGN feedback on SMBHs, galaxies and their multi-phase ISM across cosmic time
Yu	R-B14	Black Hole Masses from the OzDES Reverberation Mapping Project

Oral & Poster Programme Abstracts

Monday, 26th September 2022

Session 1: How does the gas accrete onto black holes, from kpc to sub-pc scales?

How does the monster take its meals?

Françoise Combes | Observatoire de Paris

Abstract

The way matter can be accreted to grow the black hole has always been a problem, since the 1970' years. The black hole may swallow stars with a low angular momentum, but they are quickly depleted, and relaxation is quite long to refill the loss cone. Even if the gas reservoir around the black hole is abundant, the feeding remains difficult, because of its enormous angular momentum, to be exchanged away. Viscous torques are negligible, but gas can cool and dissipate energy in cloud collisions and shocks, and may be driven in through gravity torques from the non-axisymmetric potential, due to bars and spirals, maybe fostered by mergers. Primary bars can exchange angular momentum with the gas inside corotation, which will spiral inwards until the inner Lindblad resonance. Then an embedded nuclear bar can take over. When gas is reaching the sphere of influence of the black hole, the torque turns to negative, fueling the center. Closer to the nucleus, dynamical friction also accelerates the infall of gas clouds. Due to the Eddington rate limit, growing a black hole from a stellar-mass seed is long, and the observation of very massive black holes in the early universe is a puzzle that could be solved through direct collapse of massive clouds into black holes, or the possibility of super-Eddington accretion.

Current results on Sgr A* and M87, and the future of the EHT

Angelo Ricarte | Center for Astrophysics – Harvard & Smithsonian

Abstract

The Event Horizon Telescope (EHT) has produced the first resolved images of black holes, providing new insights into accretion and feedback on event horizon scales. I will summarize how our resolved images constrain the magnetic field state of these accretion flows. Our studies of the largest black holes on the sky are very much not over, and will include circular polarization, spectral index, and rotation measure maps in the future. Finally, the next-generation Event Horizon Telescope (ngEHT) aims to create movies, obtain multi-frequency images, and expand the dynamic range to capture accretion and jet launching simultaneously

Milky Way's Galactic Center black hole in its natural habitat

Lena Murchikova | Institute for Advanced Study & Harvard University

Abstract

The Milky Way's Galactic Center black hole Sagittarius A* is the closest to us supermassive black hole. It is an ideal candidate to explore near horizon effects, and to test our understanding of the mechanics of black hole feeding, accretion, and feedback – forces shaping galaxies and the Universe as a whole. Despite its proximity, the accretion flow onto it is not well understood. At large scales ($10^5 R_s ch$ and beyond), the primary source of information about accretion flow comes from observations of hot X-ray emitting gas. At near horizon scales, the density of the flow is constrained by polarization measurements. At intermediate scales, there are too few model-independent probes to reliably determine physical properties of the gas. In 2019, using ALMA observations I discovered a disk of cool gas at intermediate distances ($10^4 R_s ch$) from the black hole, which provides new clues to the physics of the inner accretion flow of the Sagittarius A*. In this talk, I will review what is known about the structure of the accretion flow around the black hole. I will discuss the properties of the cool disk and what we can learn from it about the structure of the accretion flow. I will show our new realistic simulations of the inner two parsecs of the Galactic Center which, for the first time, captures Sagittarius A*'s multiphase accretion physics.

MATISSE results on NGC 1068: on the dust at pc scales from the AGN

Violeta Gámez Rosas | Leiden Observatory, Leiden University

Abstract

Mid infrared interferometry gives us the opportunity to study in detail the dusty structures that are very close to the super-massive black hole that lies at the center of an AGN. MATISSE, at the VLTI, is a second generation spectro-interferometer that can combine the light of four telescopes at a time. Thanks to its high spatial resolution, its broad spectral coverage and its imaging capabilities, we can learn about the distribution of the dust, its mineralogical composition, and its physical properties. In this talk I will tell you about our recent results on the prototypical Seyfert II NGC 1068. We obtain a map of temperatures of the dust and optical depths that unveil an optically thick ring obscuring the central engine at parsec scales and a less optically thick disk extending to at least 10 pc. We find that the cold obscuring dust is mainly formed by amorphous olivines and carbon grains. A meticulous analysis of absorption and emission features present in the L band correlated fluxes demonstrates that the medium is highly inhomogeneous at sub-pc scales. The absorption is from aliphatic hydrocarbons as those commonly seen in the diffuse ISM towards the Galactic center, while the emission seems to agree with that of aliphatic subgroups or super-hydrogenated PAHs. We find the dusty structures that play the role of the 'historical torus', yet the extended emission that we see in the N band suggests the presence of dusty winds.

Cosmological hyper-refinement simulations of AGN fueling and feedback

Daniel Anglés-Alcázar | University of Connecticut / Flatiron Institute

Abstract

Understanding the physical mechanisms driving galactic nuclei fueling and feedback in a cosmological context represents a major challenge owing to the huge range of spatial and temporal scales involved. Despite much recent progress, cosmological simulations have been traditionally limited by resolution, interstellar medium physics, and the sub-grid treatment of black holes. In this talk, I will present a new class of cosmological hyper-refinement simulations that for the first time resolve explicitly the transport of gas down to sub-pc scales in the nuclear regions of massive galaxies in a full cosmological setting, while modeling a realistic multi-phase interstellar medium including gas consumption by star formation, feedback from supernovae, stellar winds, and radiation, and gravitational torques from multi-scale stellar non-axisymmetries. I will then introduce a novel technique that allows us to simultaneously capture the interaction of fast accretion-disk winds with multi-phase gas from sub-pc to circumgalactic medium scales. I will highlight some of the lessons learned from these multi-scale simulations, with important implications for AGN fueling and the nature of luminous quasars, AGN duty cycle and time variability, super-Eddington feeding, the star formation-AGN connection, black hole-galaxy scaling relations, and galaxy quenching.

Simulating the building and evolution of central gas reservoirs: towards black hole fuelling

Pierrick Verwilghen | European Southern Observatory (ESO)

Abstract

The fuelling of Super Massive Black Holes (SMBHs) in disc galaxies is a complex process involving a broad range of spatial and time scales. While the fuelling itself may vary over very short timescales and be dominated by turbulent, dissipative and radiative processes, its long-term secular evolution is thought to be regulated by other larger-scale physical mechanisms (e.g., gravitational torques, viscous effects, instabilities, feedback) allowing the building (and consumption) of gas reservoirs in the central 1-100 pc region. Many avenues have already been explored, such as inner spiral arms, bars, and local instabilities, but their actual roles in setting up timescales and potential cycles are still debated. In this work, we explore the formation and evolution of central gas reservoirs through a new suite of (RAMSES) hydrodynamical simulations of isolated disc galaxies, the first step towards a better understanding of the large-scale regulation processes. Those simulations have been designed to represent main sequence disc galaxies in the PHANGS survey, via a fine grid of relevant physical parameters (i.e., stellar mass, gas fraction/distribution, bar characteristics, central SMBH mass), to systematically probe the physics driving those gas reservoirs. In this presentation, I will show, via this new suite of simulations, how gas reservoirs are built and consumed, and emphasise the role of bars and their evolution in setting up the relevant timescales at the $\sim$10pc scale. Based on the confrontation with the exquisite PHANGS datasets (ALMA, HST, MUSE), I will then present prescriptions to characterise gas inflows as a function of the intrinsic properties of the host galaxy. I will conclude by sketching the next steps for this project, to reconnect the actual SMBH fuelling with the secular evolution of gas reservoirs.

Stellar-Feedback Regulated Black Hole Growth: Connecting the Inner Regions of Galaxies to the Physics of the Circumgalactic Medium

Lindsey Byrne | Northwestern University

Abstract

Recent simulations of galaxy evolution suggest that supermassive black holes grow in two phases: inefficiently and intermittently at early times, and more rapidly later on. In this talk, I will discuss physical factors that may drive the transition between black hole accretion phases in the context of the FIRE simulations. I select a set of high-resolution hydrodynamical cosmological zoom-in simulations ranging from dwarf galaxies to galaxies sufficiently massive to host luminous quasars. I find that several properties of the galaxy across a range of scales, including halo mass, galaxy stellar mass, and stellar surface density in the central 1 kpc, correlate with rapid black hole growth: simple, constant thresholds in these properties are crossed around the time of the transition from suppressed to accelerated growth. I will discuss how stellar feedback, the virialization of the inner CGM, and the formation of stable gas disks may explain the phases of black hole accretion. I will also discuss the implications for our understanding of the importance of AGN feedback in massive galaxies.

Multiphase dynamical gas fountain that replaces the classical black hole obscuration

Takuma Izumi | National Astronomical Observatory of Japan

Abstract

The unification scheme of active galactic nuclei (AGNs) postulates that our viewing angle through a putative dusty/gaseous torus determines the visibility of the central engine. In recent years, properties of such compact tori (∼10 parsec-scale) have finally begun to be clarified, including warm dust along the disc polar direction and dense gas concentrations. Despite these progresses, their multiphase gas nature and dynamics at the innermost parsec-scale remain unresolved, which hinders our understanding of the physical origin of torus and fueling to the black holes. Here, based on 0.5-2.6 parsec-resolution submillimetre observations, we demonstrate that different phase gases at the central $r < 5$ parsecs of the Circinus galaxy (the nearest obscured AGN) participate in different dynamical flows. We found that dense molecules form a thin, Keplerian disc with inflows at a sufficiently high rate to sustain this AGN luminosity. We identified this inflow motion as a deep inverse P-Cygni profile (absorption) toward the continuum source. Diffuse atomic gas shows AGN-driven slow outflows (∼40 km/s) that eventually fall back to the disc. This vertical gas motion makes the aspect ratio of the atomic disc (∼0.5) sufficiently high to obscure the nucleus. We finally pinned down a launching site of fast (∼200 km/s) ionized outflows that clarify the origin of the polar dust elongation. Our observations provide a highly dynamic picture of circumnuclear gas feeding and feedback, which will fundamentally replace the classical torus-based AGN obscuration.

Getting wise to the role of cold molecular gas in AGN fueling

Timothy Davis | Cardiff University

Abstract

AGN are a crucial part of our galaxy evolution paradigm, but what fuels their activity, and how gas moves from large to small scales is not well understood. In this talk I will show how the WISDOM survey, which maps the molecular gas in nearby galaxy nuclei on parsec scales, can constrain these questions. This survey's extremely high-resolution ALMA data allows one to estimate black hole masses, but crucially also reveals the properties and kinematics of the circumnuclear molecular gas in a sample of more than 40 galaxies spanning a range of AGN types. I will show that slow streaming inflow motions are common within the circumnuclear gas discs, providing a flow of gas from kpc to pc scales, and discuss how the properties of these inflows vary with galaxy/AGN type. In addition, I will show that the amount of molecular gas on small scales around the nucleus correlates well with long time scale accretion measures (such as radio emission) in all types of AGN - but not with short timescale tracers (e.g. X-rays). This suggests that, where present, accretion of cold gas may be as important in low-luminosity and low-excitation sources as it is in high luminosity/excitation AGN.

On the study of torus disappearance in LLAGN as seen through X-rays

Natalia Osorio Clavijo | Instituto de Radioastronomía y Astrofísica UNAM (IRyA)

Abstract

It has been proposed that both the torus can be explain as a wind coming off the accretion disk. From this point of view, such structure should disappear for bolometric luminosities below Lbol $= 10^{42}$ erg/s, as the radiation pressure is no longer capable of counteract gravity. However, recent studies show that this structure can disappear for bright sources, suggesting that its disappearance does not only depend on the bolometric luminosity, but on more complex wind parameters. At X-rays, the torus can be studied through the reflection component, which has long been associated with this region. In this work, we present results from a sample of Low-luminosity AGN (AGN) observed with NuSTAR with a wide range of black hole masses in order to study the behavior of the reflection component which peak at energies above 10 keV, and try to understand the conditions under which such a component can disappear. We find 11 candidates for the torus disappearance, all which can be fitted with a single power-law with little or no obscuration. Moreover, all these sources are located in the region in which the torus may or may not disappear depending on the wind parameters. We find that when it exists, the reflection accounts for around 40% of the intrinsic continuum, and we also find a change in the contribution of the FeKα line which goes from 1% to 10% of the reflection component, which suggests a chemical evolution with Eddington rate.

An X-ray and Radio View of the different modes of AGN Accretion and Feedback with eROSITA and LOFAR

Zsofi Igo | MPE

Abstract

The eFEDS survey, the pilot field of the eROSITA All Sky Surveys which reaches an unprecedented combination of sky coverage and X-ray sensitivity, as well as overlapping with the GAMA09 region, offers a unique avenue to explore the versatility of the multiwavelength sky. In this project, we conduct a uniform and systematic analysis of AGN sources, aiming to understand the different correlations that exist between sub-pc (accretion) and larger scale (galaxy) parameters. To do this, we find radio and optical/UV counterparts to the eFEDS AGN from the LOFAR 150MHz and Legacy DR9 catalogues, respectively, using a Bayesian algorithm called NWAY. Furthermore, we use new SDSS-V optical/UV spectra to obtain black hole masses, and thus accretion rates, along with several emission line properties serving as potential indicators of AGN feedback through winds (e.g. O[III]λ5007Å). Combining this wealth of multiwavelength observations on around 1000 sources, allows us to make insightful conclusions the behaviour of the 'Fundamental Plane of AGN' at different Eddington ratios, coronal/accretion disk geometries and the mechanisms of AGN feedback, such as the connection between winds and jets.

Uncovering the missing population of dual AGNs with Gaia

Filippo Mannucci | INAF - Arcetri

Abstract

All cosmological models of structure formation predict the existence of a widespread population of dual SMBHs in-spiraling inside their common host galaxy with separations of a few kpc (sub-arcsec separations at $z > 1$) eventually merging and giving rise to intense gravitational waves emission. Identifying these systems is a difficult task: only 4 systems are confirmed with separations below 8 kpc at $z > 1$. We will present the novel 'Gaia Multi Peak (GMP)" method that takes advantage of the unique capabilities of the Gaia satellite to obtain large and reliable samples of hundreds of dual or lensed AGN candidates with sub-arcsec separations (Mannucci et al 2022, Nature Astronomy). HST and high-resolution LBT images of a few tens of selected systems reveal the presence of multiple sources in all of them, with separations of 0.2"-0.7", confirming the high efficiency of this method. We will also present A0-assisted spatially-resolved spectra obtained at Keck and near-IR colors from LBT to study the nature of a few such systems. Sampling separation down to 2kpc at $z > 1$, this technique allows us to probe the physical processes driving the inspiraling of the pairs of SMBH inside a single galaxy.

Anatomy of molecular dusty tori and nuclear outflows in nearby AGNs

Santiago García-Burillo | OAN-Spain

Abstract

ALMA has made possible to study the distribution and kinematics of molecular gas in active galaxies down to ∼parsec scales. We review the last results derived from a number of high-resolution ALMA surveys imaging molecular tori in a representative sample of AGNs in the local universe (NUGA and GATOS). The GATOS project expands the range of AGN luminosities and Eddington ratios covered by previous surveys and allows us to study the gas feeding and feedback cycle in a combined sample of 19 Seyferts with spatial resolutions ∼7-10pc. These observations detect 870 μm continuum and molecular line emission stemming from spatially-resolved molecular dusty disks, which tend to be perpendicular relative to the AGN wind axes, as expected for dusty molecular tori. The median values of the sizes and molecular gas masses of the tori are $\sim$ 42 pc, and $\sim 6 \times 10^5$ Msun, respectively. The inner section of these disks are within the sphere of influence of the BH. The radial distributions of molecular gas in the circumnuclear disks (CND) of the targets show the imprint of AGN feedback reflected in the presence of nuclear-scale molecular gas deficits, which are more extreme in higher Eddington ratio sources and linked to the detection of molecular outflows. More recently, new 2-3pc spatial resolution images of two galaxies of the sample have fully resolved the tori and their dusty winds associated with polar components with unprecedented detail. We discuss an extension of the survey to higher AGN luminosities more akin to those of QSO-like sources.

Extended warm dust nuclear emission in nearby Seyfert galaxies

Almudena Alonso Herrero | Centro de Astrobiología (CSIC-INTA)

Abstract

Simulations of dense clumpy dusty disks around active active nuclei (AGN) predict the launch of dusty winds. The wind strength and orientation is found to depend on the AGN Eddington ratio and the column density of the dusty clumps. I will present high angular resolution mid-IR observations of nearby Seyfert galaxies obtained with ground-based telescopes. In more than half of the sample, we detected extended nuclear mid-IR emission on scales of 50-160pc. The extended emission is seen mostly perpendicular to the ALMA dusty molecular tori, that is, in the polar direction. However, the unresolved mid-IR component contributes more than 60% of the emission in our ∼0.3" resolution mid-IR observations. The Eddington ratios and nuclear hydrogen column densities of those Seyferts with extended mid-IR emission are favorable to launching nuclear polar and/or equatorial dusty winds. We also generated new radiative transfer CAT3D-WIND disk+wind models and mid and far-IR model images. We tailored these models to the properties of the Seyferts in this work. The characteristic "X"-shape associated with dusty winds is seen better in the far-IR and at intermediate-high inclinations for the extended-wind configurations. In most of the explored models, the mid-IR emission mainly comes from the inner part of the disk and cone. Extended biconical and one-sided polar mid-IR emission is seen in extended-wind configurations. I will also present torus/disk and disk-wind predictions for color-color diagrams and model images using JWST/MIRI imaging filters in the 5-21micron range. For our upcoming Cycle 1 observations, we selected five MIRI filters to probe dust continuum emission and the 9.7micron silicate feature, while avoiding spectral regions with strong PAH emission. Our goal is explore the nature of the low surface-brightness extended warm dust emission detected in the selected Seyfert galaxies.

A1 Studying the Structure of the Obscuring Torus using Eddington Ratio

Tonima Tasnim Ananna | Dartmouth College

Abstract

We determine the low-redshift X-ray luminosity function (XLF), active black hole mass function (BHMF), and Eddington-ratio distribution function (ERDF) for both unobscured (Type 1) and obscured (Type 2) active galactic nuclei (AGN) using the unprecedented spectroscopic completeness of the BAT AGN Spectroscopic Survey (BASS) data release 2. In addition to a straightforward 1/Vmax approach, we also compute the intrinsic distributions, accounting for sample truncation by employing a forward modeling approach to recover the observed BHMF and ERDF. As previous BHMFs and ERDFs have been robustly determined only for samples of bright, broad-line (Type 1) AGNs and/or quasars, ours is the first directly observationally constrained BHMF and ERDF of Type 2 AGN. We find that after accounting for all observational biases, the intrinsic ERDF of Type 2 AGN is significantly skewed towards lower Eddington ratios than the intrinsic ERDF of Type 1 AGN. This result supports the radiation-regulated unification scenario, in which radiation pressure dictates the geometry of the dusty obscuring structure around an AGN. Calculating the ERDFs in two separate mass bins, we verify that the derived shape is consistent, validating the assumption that the ERDF (shape) is mass independent. We report the local AGN duty cycle as a function of mass and Eddington ratio, by comparing the BASS active BHMF with the local mass function for all SMBH. We also present the log N-log S of Swift-BAT 70-month sources.

A2 The role of galaxy mergers in fuelling active galactic nuclei

Mathilda Avirett-Mackenzie | University of Bath

Abstract

Galaxy mergers have the potential to trigger active galactic nucleus (AGN) activity through their ability to funnel cold gas to the centre of the galaxy. However, their dominance as a triggering mechanism is a subject of much debate. In particular, it is unclear how merger rate changes with AGN luminosity, obscuration, and Eddington ratio. This has historically been challenging to study due to the difficulty of identifying galaxy merger signatures; however, machine learning has revolutionised this area in recent years with its ability to efficiently and accurately detect mergers. In this work, we use a Convolutional Neural Network (CNN) to identify and compare the merger rates of Type 2 AGN hosts and a matched sample of non-AGN in the Sloan Digital Sky Survey (SDSS). The CNN is trained on a dataset for which the physical ground truth is known: observationally-realistic images of galaxies from the IllustrisTNG simulation which have undergone a major merger ($\mu > 0.25$) in the last 0.5 Gyr, and a control sample which have undergone no significant mergers in the last 2 Gyr. We then use the CNN to predict the probability of each SDSS galaxy having recently merged and derive a merger rate for the AGN and non-AGN host galaxies. Finally, we compare the results of the CNN to the more traditional methods of visual inspection and asymmetry measurements. Future work includes applying the CNN to observations of Type 1 AGN to compare the merger rates of AGN hosts at different levels of obscuration.

A3 Broadband X-ray Spectroscopy as a Probe of AGN Obscuring Structures

Mislav Balokovic | Yale University

Abstract

Gas and dust structures obscuring the immediate environment of actively growing supermassive black holes form an integral part of the accretion flow that transports material from kpc to sub-pc scales. They are directly observable in the majority of the AGN population both nearby and at high redshift. Recent X-ray spectroscopy results suggest that the covering factor of the "obscuring torus" peaks around the typical Seyfert luminosity and decreases toward both lower and higher luminosities. I will present measurements of the basic structural parameters of the obscurer using single-epoch, broadband X-ray data for a large sample of nearby AGN, which became available within the last decade thanks to the hard X-ray sensitivity of NuSTAR. Using an exemplary low-luminosity AGN, I will show how radio and infrared interferometry can be folded into new X-ray spectral models for structures such as the broad and narrow emission line regions and the obscuring torus. On the high-luminosity end, I will present new results on constraining the torus geometry in obscured, moderate-redshift quasars recently observed with XMM-Newton and NuSTAR, and discuss how this will inform similar studies with Athena at even higher redshift.

A4 Watching a Little Gas Cloud G2 orbiting the Galactic Supermassive Black Hole

Andreas Burkert | University of Munich

Abstract

This talk will summarize what we know (and don't know) about the little 3 Earth mass gas cloud G2, orbiting the central supermassive black hole of the Milky Way. Is G2 a diffuse gas clump that originates from winds of high-mass stars in the surrounding stellar disk or is it the atmosphere of an evaporating, invisible protostellar disk, surrounding a young low-mass stars. Or is it something completely different? The existence of such a tiny, cold gas cloud in the hostile vicinity of the SMBH raises numerous fascinating questions related to its structure and the accretion of gas onto the SMBH. Where did G2 come from and where will it go? Why is it on such a highly eccentric orbit? Which physical processes constrain its properties like its size, mass, density, temperature and geometrical shape? How many clouds like G2 are currently orbiting Sgr A* and how do they affect its activity and gas accretion rate?

A5 The dependence of QSO accretion disk size on black hole mass

Alice Eltvedt | Durham University

Abstract

Less than 100 QSOs have the well measured black hole masses which are crucial for understanding AGN black hole and accretion disc physics. Our first aim is to dramatically improve knowledge of the active BH mass function at $0.5 < z < 3$ using an efficient, 'stacked' reverberation mapping technique. In reverberation mapping, the radius of the BLR is measured by the time lag between the continuum and broad line strength. Given this radius and an estimate of the velocity dispersion of BLR gas clouds from the FWHM of an emission line, the BH mass can be estimated from the virial relation. I present a comprehensive QSO dataset along with preliminary results of the stacked reverberation mapping of 7500 AGN in over $\sim$70 deg^2 of the eFEDS G09 field. Crucially, these 7500 QSOs are also being monitored in the X-ray so that in addition we can measure the accretion disk size from the X-ray - optical time lag. These accretion disc sizes can then be compared to our measured black hole masses to probe, for the first time, this fundamental relationship that is central to both AGN and black hole physics.

A6 AGN variability in the Ultra Deep Survey

Karel Green | University of Nottingham

Abstract

AGN activity is now considered a possible phase in potentially any galaxy's evolution, but the mechanisms behind its multiwavelength emission are not fully understood. We do know, however, that AGN emission is not static, but actually varies in brightness over time, and we are able to take advantage of this property to probe its structure. Infrared emission probes the dusty torus of AGN, but since variability timescales increase with wavelength these areas are significantly less well studied compared to more central parts. In this research we make use of almost a decade of NIR observations the Ultra Deep Survey (UDS) was the first to provide. These bands allow us to study the hottest part of the dusty torus and outer edges of the accretion disk of AGN. This combined with two samples of active galaxy, one selected from complimentary Chandra X-ray data and a new sample found purely on their NIR variability allows us to see if and how the farthest edges of the AGN mechanism is connected to accretion onto the central black hole...

A7 Multi-Wavelength Properties of Local Active Galactic Nuclei

Kriti Kamal Gupta | Universidad Diego Portales, Santiago

Abstract

A characteristic property of accreting supermassive black holes (SMBHs), also known as active galactic nuclei (AGN), is that they emit radiation over the entire electromagnetic spectrum. Hence, a detailed study of the multi-wavelength spectral energy distributions (SEDs) of a complete sample of AGN would provide fundamental insights into their accretion properties. Thanks to the high penetration power and low host galaxy contamination of hard X-rays (>10 keV), they can provide an almost unbiased sample of nearby AGN. Various important quantities like bolometric luminosity and Eddington ratio can be calculated from a detailed analysis of AGN SEDs. Reliable estimates of bolometric corrections can be further used to estimate the intrinsic luminosity of an AGN sample without the need for their multi-wavelength data. Furthermore, different theoretical and computational disk models can be used to fit AGN SEDs and better understand AGN physics. In my work, I studied the multi-wavelength properties of hard X-ray selected AGN from the 70-month Swift/BAT catalog, focussing on unobscured type 1 AGN from the BASS (BAT AGN Spectroscopic Survey) Data Release 1 and 2. I have compiled and processed high-quality, simultaneous, multi-wavelength photometric data for our sample, including optical and UV data in 6 filters from Swift/UVOT and X-ray data from Swift/XRT. I have used GALFIT to obtain the optical/UV AGN fluxes for our sources and fitted their X-ray spectra using XSPEC to create their optical to X-ray SEDs. In this talk, I will present some results from my Ph.D. research, including optical and X-ray bolometric corrections based on the optical/UV image decomposition and the optical to X-ray SED modeling done for our sample of 330 type 1 Swift/BAT AGN.

A8 Gas inflows in the polar ring of NGC 4111: the birth of an AGN

Gabriel Roberto Hauschild Roier | Universidade Federal do Rio Grande do Sul

Abstract

We have used Hubble Space Telescope (HST) images, SAURON Integral Field Spectroscopy (IFS), and adaptative optics assisted Gemini NIFS near-infrared K-band IFS to map the stellar and gas distribution, excitation and kinematics of the inner few kpc of the nearby edge-on S0 galaxy NGC 4111. The HST images map its $\asymp$450 pc diameter dusty polar ring, with an estimated gas mass $\geq 10^7\,\mathrm{M}_\odot$. The NIFS data cube maps the inner 110 pc radius at $\asymp$7 pc spatial resolution, revealing a $\asymp$220 pc diameter polar ring in hot (2267$\pm$166 K) molecular H2 1-0 S(1) gas embedded in the polar ring. The stellar velocity field shows disc-dominated kinematics along the galaxy plane both in the SAURON large scale and in the NIFS nuclear-scale data. The large-scale [O III] λ5007 Å velocity field shows a superposition of two disc kinematics: one similar to that of the stars and another along the polar ring, showing non-circular motions that seem to connect with the velocity field of the nuclear H2 ring, whose kinematics indicate accelerated inflow to the nucleus. The estimated mass inflow rate is enough not only to feed an active galactic nucleus (AGN) but also to trigger circumnuclear star formation in the near future. We propose a scenario in which gas from the polar ring, which probably originated from the capture of a dwarf galaxy, is moving inwards and triggering an AGN, as supported by the local X-ray emission, which seems to be the source of the H2 1-0 S(1) excitation. The fact that we see neither near-UV nor Br γ emission suggests that the nascent AGN is still deeply buried under the optically thick dust of the polar ring.

A9 Observing Intermediate-Peaked Blazars with VERITAS

Claire Hinrichs | Dartmouth College

Abstract

The spectral and temporal behavior of blazars, especially at very high energies, sheds light on the radiative processes that drive their non-thermal emission. VERITAS is one of the most sensitive ground-based gamma-ray observatory in the world, and is able to detect gamma-ray energies exceeding 100 GeV. Using VERITAS, we have observed and analyzed the VHE emission of select intermediate-peaked BL Lac objects. The preliminary results of these studies will be presented.

A10 The Dusty Heart of Circinus: Imaging the Circumnuclear Dust in N-band

Jacob Isbell | Max Planck Institute for Astronomy

Abstract

Active galactic nuclei play a key role in the evolution of galaxies, but their inner workings remain shrouded in dust and in mystery. Infrared interferometry makes it possible to resolve the circumnuclear dust in the nearby Seyfert 2, the Circinus Galaxy. Previous observations with MIDI revealed complex structures and polar dust emission but morphology analysis was limited to simple models. VLTI/MATISSE allows us to image these structures for the first time. We observed the Circinus Galaxy with VLTI/MATISSE, producing 150 correlated flux spectra and 100 closure phase spectra. We reconstruct images in the N-band at $\sim$10 mas resolution. We fit blackbody functions with dust extinction to several aperture-extracted fluxes from the images to produce a temperature distribution of the central dusty structures. We find significant substructure in the circumnuclear dust: a central unresolved component, a thin disk 1.9 pc in diameter oriented along PA $\sim$ 45 degrees, and $\sim$ 4 x 1.5 pc polar emission extending orthogonal to the disk. The polar emission exhibits patchiness, which we attribute to clumpy dust. Flux enhancements to the East and West of the disk are seen for the first time. The temperature profiles of the disk and of the polar emission differ: the disk shows a steep temperature gradient indicative of denser material; the polar profile is flatter, indicating clumpiness and/or lower dust density. The unresolved flux is fitted with a high temperature, $\sim$ 370 K. The polar dust remains warm ($\sim$ 200 K) out to 1.5 pc from the disk. The spatially resolved subparsec features imaged here place new constraints on the physical processes present in active galactic nuclei. Our images show for the first time directly the complexity of circumnuclear dusty outflows.

A11 Unveiling the origin of hard X-ray emission of Centaurus A with multi-epoch NuSTAR observations: disk or jet?

Toshiya Iwata | The University of Tokyo

Abstract

Centaurus A (Cen A) is one of the most suitable objects to study the active galactic nucleus (AGN) jet and the relation between the AGN jet and the accretion disk due to its proximity. Nevertheless, the origin of the hard X-ray emission of Cen A is still uncertain. To study the origin, we analyze the X-ray light curves and the four-epoch hard X-ray spectra observed with the Nuclear Spectroscopic Telescope Array (NuSTAR), taking the time lag of the reflection component into account. By comparing the light curves of the hard X-ray continuum observed from Swift/Burst Alert Telescope and that of the Fe Kα fluorescence line, we find that the reflector has two scales, $< 0.24 \sim \mathrm{pc}$ and $> 1.8 \sim \mathrm{pc}$. The spectral analysis using this result reveals that the origin of the reflection component is optically thin for Compton scattering. These results indicate that the reflection component comes from the Compton-thin AGN torus. We also find that the primary component can be explained by a cutoff power-law model and that the change of its photon index is $\lesssim 0.1$. Considering the relation between X-ray and radio flux density, these results suggest that the emission associated with accretion disk dominates in the energy range (4–$78 \sim \mathrm{keV}$), although we cannot rule out the jet origin scenario.

A12 Multi-wavelength follow-up of extreme variability in AGN detected with eROSITA

Mirko Krumpe | Leibniz-Institute for Astrophysics Potsdam (AIP), Germany

Abstract

The eROSITA all sky X-ray survey has provided the basis for a large-scale and systematic search for extreme X-ray variability in extra-galactic objects, associated with large accretion changes in supermassive black holes. We have combined the survey data-set with a multi-wavelength follow-up campaign of the most variable objects, including optical spectroscopy, X-ray, and UV observations. In the talk, I will cover the results of our search covering the first two years of eROSITA's operation, consisting of four X-ray epochs for each object. I will introduce our sample of extremely variable sources by detailing our selection methods. In total our sample consists of ∼2,000 vetted sources, of which approximately 10% have additional follow-up data. I will provide an overview of some of the most interesting sources detected (extreme ignition and shutdown events in AGN). Finally, I will discuss our results in the context of the link between extreme X-ray and optical variability, specifically 'changing-look' behaviour in AGN, and the time-scales involved in large scale accretion changes around SMBHs.

A13 Disc reverberation of a rapidly-growing black hole

Daniel Kynoch | University of Southampton

Abstract

We present the latest results from the major *Swift* monitoring campaign on the bright active galactic nucleus (AGN) MCG +08−11−11. Reverberation mapping of the accretion disc gives insight into the innermost structure of an AGN during a phase of rapid growth. Black holes grow by accreting material from the disc surrounding them. To fully understand the growth of supermassive black holes on the smallest scales ($<\sim$pc), we need a clear picture of the inner AGN geometry. Since accretion discs cannot be spatially resolved we indirectly map their structure by determining how they reverberate with the variable, central, X-ray source. Observations of correlated UV/optical variations, with time lags increasing with wavelength, broadly confirm that discs reprocess X-rays on short timescales (days). However, a number of intriguing puzzles have emerged: On longer timescales (weeks-months), why are X-ray and UV/optical variations different? How does the broad line region contribute to longer lags? Why do UV/optical lags imply discs 2–3$\times$ larger than predicted? Why are long-wavelength lags sometimes much shorter than expected? Many of these issues relate to the accretion rate ($\dot{m}$), but most previous reverberation campaigns have been performed on low-$\dot{m}$ AGN. We have conducted, for the first time, *Swift* monitoring of the high-$\dot{m}$ ($\gtrsim 50$ $\sim$% Eddington) AGN MCG +08−11−11 over two years. Intensive sampling ($3\times$ daily) over three months enables a precise determination of the lag spectrum and short-term variability properties. Trends at longer timescales and wavelengths are investigated by incorporating ground-based observatory data. We have observed shorter-than-expected long-wavelength lags in another AGN that may be due to outer disc truncation; hints of this are also seen in the MCG +08−11−11 data. This rich data set will provide insights into the geometry and processes of the material feeding a rapidly-growing black hole.

A14 Black holes masses from 'industrial-scale' Reverberation Mapping with OzDES

Umang Malik | Australian National University (ANU)

Abstract

The Australian Dark Energy Survey (OzDES) has monitored almost 800 Active Galactic Nuclei over 6 years to conduct one of the first 'industrial-scale' reverberation mapping (RM) programs. The strength of reverberation mapping lies in its ability to resolve the innermost regions of AGN in the time-domain, rather than spatially, allowing us to study these compact cores out to high redshifts. This is crucial to understanding how supermassive black holes and galaxies evolve over cosmic time. I will present the latest results from the OzDES survey, including some of the highest redshift measurements made to date. Our updated Radius-Luminosity relations for the Hβ, MgII, and CIV lines will be used to estimate single-epoch virial black hole masses for thousands of AGN. I will conclude by showing how future RM surveys, including LSST (VRO), TiDES (4MOST) and SDSS-V, can improve their efficacy.

A15 Origins of broad line region probed by reverberation mapping and multi-wavelength observation of an extremely variable Changing-State Quasar

Shumpei Nagoshi | Kyoto University

Abstract

While the unified model of quasar structure provides a concise description of diverse spectra, the physical origins of the components are yet unresolved. We focused on Changing-State Quasar (or Changing-Look Quasar) as a research target to explore the physical origin of the unified model. The reason is that observing structural changes associated with state transitions can provide insight into the origins of each structure. We aimed to understand the central core structure of the Changing-State Quasar and its changes before and after the state transition. As the research target, we selected SDSS J1258, which exhibited one of the most significant variations in the history of observations (Nagoshi et al. 2021). We performed reverberation mapping by optical spectroscopy to measure the black hole mass and investigate the structure of the broad line region. We also measured the time lag between the WISE light curve and optical light curve to investigate the size of the dust torus. In addition, we compared UV and X-ray spectral index (α_{OX}) before and after the state transition to investigate the structure difference of the accretion disk. The results of the reverberation mapping show that the black hole mass is $4 \times 10^9 \mathrm{M}_\odot$ and the Eddington ratio changed from 0.008 to 0.040 before and after the state transition. The changes in α_{OX} and the Eddington ratio were consistent with those predicted from the instability due to hydrogen ionization of the accretion disk. The change in the shape of the broad lines indicates that two components exist in the broad line region. One of these components was relatively fast and disk-shaped yet unaffected by the continuum luminosity change. We suggest this component is an accretion gas component from the dust torus, and our results put a restriction on the origin of the broad line region.

A16 The importance of galaxy mergers and interactions for triggering radiatively-efficient AGN in the local universe

Jonny Pierce | The University of Hertfordshire

Abstract

Galaxy mergers and interactions can cause inflows of large amounts of gas towards galaxy centres, and they hence provide an attractive mechanism for triggering active galactic nuclei (AGN). Despite this, previous searches for observational signatures of these events in AGN host galaxies have produced mixed results, and their importance for AGN triggering therefore remains an active source of debate. To this end, we have recently conducted a deep optical imaging survey of a large sample of local active galaxies (3CR radio galaxies, intermediate-radio-power HERGs, and Type 2 quasars), in order to classify the host morphologies randomly and blindly alongside stellar-mass- and redshift-matched non-active control galaxies and determine the rates of disturbance. From this, we find that the hosts of radiatively-efficient AGN exhibit an enhancement in disturbance rate relative to the matched controls that increases strongly with AGN power, such that the objects with quasar-like [OIII]λ5007 emission line luminosities show a 5.5σ excess. In this talk, I will provide an overview of this recent work and its implications for the importance of galaxy mergers and interactions for triggering radiatively-efficient AGN in the local universe. I will also argue that differences in the surface brightness depths of the observations, combined with the effects of cosmological surface brightness dimming, could explain much of the apparent ambiguity that surrounds observational results in this field.

A17 SALT Spectropolarimetry of Blazars

Stephanie Podjed | Dartmouth College

Abstract

Spectropolarimetry is a powerful tool that led to the AGN geometric unification scheme and continues to allow us to investigate AGN central regions. Blazars are AGN with a relativistic jet that is aligned with our line-of-sight and whose optical emission is usually dominated by non-thermal synchrotron emission, leading to a continuum linear polarization that is typically greater than a few percent. For other Type 1 AGN, such as quasars, the inclination angle is not well known and due to the direct quasar light, the polarization signal can be diluted, resulting in polarization levels less than a few percent. In this study, we present preliminary results on optical linear polarization percentage and position angle of a sample of southern hemisphere gamma-ray active and quiescent blazars in the redshift range 0.116 $<$ z $<$ 1.522 , with a focus on FSRQ PKS 1510-089, to determine how the head-on orientation or the presence of a jet influences spectropolarimetric variations of blazars in the broad lines and continuum. The medium resolution (R 2000) optical spectropolarimetric data used for this study were obtained approximately bi-weekly from the Robert Stobie Spectrograph on the Southern African Large Telescope (SALT) in Sutherland, South Africa.

A18 Determining the intrinsic relation between X-ray and UV/optical tracers of supermassive black hole growth

Amy Rankine | Institute for Astronomy, University of Edinburgh

Abstract

Understanding the relationship between the UV/optical emission from the accretion disc and the X-ray emission associated with the corona is vital to understand differing AGN accretion states and thus the growth phases of black holes. The optical-to-X-ray spectral slope describes the relative strength of the hard X-rays to the accretion disc emission which peaks in the UV. The well-established anti-correlation between α_{ox} and UV luminosity has long suggested that the more luminous the quasar, the weaker the corona and the weaker the hard ionising radiation. However, this observational α_{ox} relation is subject to selection effects and biases. Utilising the optically-selected sample of AGN in the XXL field ($0.5 < z < 4$), alongside their XMM X-ray observations, we have carefully controlled for the X-ray incompleteness, by way of maximum likelihood fitting, to derive the distribution of X-ray and UV luminosities and the intrinsic α_{ox} relation, while accounting for any possible redshift evolution. As a result, we can evaluate our understanding of the connection between the accretion disc and corona.

A19 Consistent Analysis of Type-2 AGN Spectra with QSFit

Matthew Selwood | University of Bristol

Abstract

Current and future extragalactic spectroscopic surveys are producing never-before-seen volumes of AGN spectra, which require fast, reliable and consistent analysis. QSFit, a Julia language-based automatic AGN spectral fitting code, provides a means to efficiently fit and analyse the properties of large samples of unobscured (type-1) AGN optical spectra. We adapt QSFit's fitting routine for the analysis of obscured (type-2) AGN spectra, testing our modifications for self-consistency and consistency with other emission line fitting methods through the analysis of a sample of 887 optically selected type-2 AGN spectra from the SDSS presented in Reyes et al. (2008). Results indicate consistency between type-2 AGN emission line measurements made with QSFit and alternative methods as well as self-consistency of sample spectral properties with theoretical predictions. Outliers in these consistency checks point towards poor quality spectra and spectra with physically interesting emission line profiles, which cannot be effectively modeled by our general model. These cases have led to the development of specialized QSFit fitting routines for type-2 AGN spectra with high signal to noise ratios and sources with double-peaked emission lines for which additional components are required.

A20 NuSTAR Observations of 52 Compton-thick Active Galactic Nucleus Candidates Selected by the Swift/Burst Alert Telescope All-sky Hard X-Ray Survey

Atsushi Tanimoto | The University of Tokyo

Abstract

We present the systematic broadband X-ray spectral analysis of 52 Compton-thick ($24 \leq \log N_{\rm H}^{\rm LOS}/{\rm cm}^{-2}$) active galactic nucleus (CTAGN) candidates selected by the Swift/Burst Alert Telescope all-sky hard X-ray survey observed with Chandra, XMM-Newton, Swift/X-ray Telescope, Suzaku, and NuSTAR. We use an X-ray spectral model from a clumpy torus (XClumpy) to determine the torus properties such as the hydrogen column density along the line of sight, the hydrogen column density along the equatorial direction, and the Compton-thin torus covering factor. As a result, the hydrogen column density along the line of sight ($N_{\rm H}^{\rm LOS}$) obtained from the XClumpy model indicates that 24 objects are Compton-thin AGNs and 28 objects are Compton-thick AGNs in a 90% confidence interval. The main reason is the difference in the torus model applied. The hydrogen column density along the equatorial direction $N_{\rm H}^{\rm Equ}$ of CTAGNs inferred from the XClumpy model is larger than that of less obscured AGNs. The Compton-thin torus covering factor (C_{22}) obtained from the XClumpy model is consistent with that of the radiation-regulated AGN unification model in the low Eddington ratio ($\log R_{\rm Edd} \leq -1.0$), whereas C22 inferred from the XClumpy model is larger than that of the radiation-regulated AGN unification model in the high Eddington ratio ($-1.0 \leq \log R_{\rm Edd}$). These results suggest that the structure of CTAGN may be intrinsically different from that of less obscured AGN.

A21 A New Sample of Soft X-ray Bright AGNs: X-ray spectra and UV to X-ray SEDs

Yuichi Terashima | Ehime University

Abstract

Mass accretion is a key process in the growth of supermassive black holes. In the local universe, highly accreting AGNs tend to show a strong soft X-ray excess, a steep power law, and a big UV bump. It is of importance to fully understand observational properties of such objects to unserstand the physics behind their rapid mass accretion and to make an efficient survey strategy at high redshifts. We define a new sample of soft X-ray bright AGNs selected from XMM-Newton serendipitous source catalogue and XMM-OM serendipitous ultraviolet source survey catalogue. We apply conditions of small hardness ratios in the soft X-rays, sufficient full band X-ray counts, and UV detection to derive UV to X-ray slope, and then construct a sample consisting of 158 observations of 36 AGNs We find various shapes of X-ray spectra, which are missed in many of previous works. The spectra of most objects are represented by a combination of a steep power law and a soft excess, which are often seen in narrow-line Seyfert 1s. Three objects show extremely soft X-ray spectra represented by a power law with a photon index of 3-5. The power law component of at least four objects is significantly absorbed, while their soft emission does not show signatures of absorption. We will present the results of our systematic spectral analysis and summarize their X-ray properties and UV to X-ray SEDs.

A22 Progress towards a better understanding of “Changing Look” AGN

Martin Ward | Durham University, UK

Abstract

The terminology "Changing Look AGN" as applied to optical spectroscopy is approaching its first decade. It is now quite clear that the classification encompasses a heterogenous group of AGN.The term "Changing Look" is probably now ingrained in astronomy, but a better description would be "Changing State", as this is not specific to the observational window. We have embarked on several observational studies which include tracking examples of variable objects found from satellite alerts, in addition to mining databases such as those of XMM-Newton and Swift. We have used follow-up spectroscopy and long term lightcurves to define subgroups, and hence separate supernova events, TDE's and those genuine changing look AGN. I will describe our results in terms of the underlying physics of accretion phenomena, possible jets, and variable obscuration. This information will be very relevant to forthcoming "Big Data" samples of such objects.

A23 Surveying Changing-State AGNs with SDSS-V

Grisha Zeltyn | Tel Aviv University

Abstract

Recent advances in time-domain surveys have revealed dramatic changes to SMBH accretion and AGN appearance on surprisingly short timescales. These events can provide key insights into extreme and variable modes of SMBH accretion, such as AGNs turning on and off, and super-Eddington accretion. Among those, Changing-state AGNs (CSAGNs) show the (dis)appearance of broad emission lines and/or the quasar-like continuum, on timescales of years and sometimes even months. These dramatic changes may be driven by variable accretion episodes, and can trace the reignition or shutting off of SMBH accretion. In addition, CSAGNs present the opportunity to study certain galaxies in both their active and non-active states. I will present the largest sample of (candidate) CSAGNs to date, obtained from the first year of the recently launched SDSS-V project. Our sample covers a broad range of timescales, redshifts, and black hole properties. Our preliminary analysis shows that CSAGNs occur at systems with relatively low Eddington ratios, but with no preference for certain BH masses, nor variability patterns. This disfavors tidal disruption events (TDEs) as the driver of variability. I will highlight a particularly extreme CSAGN, varying on timescales of $<$2 months, which shows the first evidence of variable obscuration in an optical spectrum of an AGN. Our large sample will allow us to gain insights into the physical mechanisms of CSAGNs, with potential implications for the unified AGN model and thus to AGN demographics.

R-A2 Studying the Variability of Quasars as a function of rest-frame wavelength from the Zwicky Transient Facility

Priyanjali Patel | Universidad de Chile, Santiago

Abstract

We present the study of the correlations between Active Galactic Nuclei (AGN) variability and rest-frame wavelength. We study a sample of optical light curves from the Zwicky Transient Facility Data Release 6 for Active Galactic Nuclei (AGN) in the r-band (6339.61 Å) and the g-band (4722.74 Å). We use homogeneous analysis of SDSS DR14 quasars by Rakshit et al.(2020) to define a sample with well-measured Black Hole mass (MBH) and Eddington ratio/accretion rate in a well-defined redshift bin. Our sample sources have 0.1 $\lesssim$ redshift $\lesssim$ 0.8, and $10^{8.0} \lesssim$ MBH/Msun $\lesssim 10^{8}.5$, while the Eddington ratio range is between $10^{-1.3}$ and $10^{-0.8}$. This sample was selected because the emission from quasars is highly variable, and variability is a potential key to understanding the accretion process. To prevent biases from redshift effects as time dilation, the light curves were corrected. Then we calculate the amplitude of variability (or variance) at different time scales in the power spectrum using the 'Mexican-Hat' filter (Arévalo et al., 2012) for 3429 sources in the g-band and 3897 sources in the r- band. Redshift is used as a tool to study different rest-frame wavelengths. In this work, we study variance on 300 and 75-day timescales and find a strong anti-correlation between rest-frame wavelengths and median variance, independent of the anti-correlation with Blackhole mass and Eddington ratio. This anti-correlation suggests that optical fluctuations in short and long timescales are less in the outer annuli than in the inner annuli if rest-frame wavelength represents the accretion disk's radius.

R-A3 Accretion disc-mediated SMBH feeding in hydrodynamical simulations

Matas Tartėnas | Center for Physical Sciences and Technology

Abstract

The large galactic scales seem to be connected to the many orders of magnitude smaller supermassive black hole (SMBH) scales by an episodic cycle of feeding and feedback. Active galactic nuclei (AGN) are powered by accretion on to the SMBH and the majority of the AGN energy, in near-Eddington regime, is produced in thin sub-pc accretion discs. Currently, it is very difficult to model processes that occur on vastly different scales, even ranging from the circumnuclear gas reservoirs at tens to hundreds of parsecs, down to the accretion disc scales at $<$0.01 pc - a difference of more than four orders of magnitude. While sub-grid prescriptions used in large scale or cosmological models are able to reproduce large scale feedback, we propose using a more realistic accretion disc model in parsec-scale simulations, where it is important to get accurate timescales to understand how feedback affects gas dynamics and star formation in the vicinity of the AGN. To test our approach we use a sub-resolution thin accretion disc model, coupled to the SMBH in a set of hydrodynamical simulations of a retrograde collision between a gas ring and a molecular cloud in an environment similar to that of the centre of the Milky Way using the 3D hydrodynamical code Gadget-3. The disc-mediated feeding of the SMBH is relatively smooth and somewhat delayed in time when compared to an instantaneous feeding prescription. While the reduction of accretion due to feedback is present in both accretion disc and instantaneous accretion models used for comparison, a clear central cavity appears only in accretion disc runs - hinting, that a less volatile accretion phase may make more of an impact on the surrounding gas.

R-A4 Heavily-Obscured AGNs and the Host Galaxies in the XMM-SERVS Fields

Wei Yan | Pennsylvania State University

Abstract

The XMM-Spitzer Extragalactic Representative Volume Survey (XMM-SERVS) contains wide X-ray coverage in three fields: XMM-LSS (5.3 deg^2), W-CDF-S (4.6 deg^2) and ELAIS-S1 (3.2 deg^2). The flare-filtered exposure times are 2.7 Ms, 1.8 Ms, and 0.9 Ms, respectively. In these observations, a total number of 11,925 X-ray point sources are reported, and over 87% of them have reliable multi-wavelength counterpart candidates. The substantial number of AGN candidates ($\approx$ 10,200) in the XMM-SERVS provides a large sample to characterize representative AGN populations, including those with heavy obscuration ($N_{\mathrm{H}} > 10^{24}\mathrm{cm}^{-2}$), along with their host galaxies. In this work, we extract X-ray spectra and perform spectral analysis to derive AGN characteristics. Using the Bayesian spectral analysis with advanced physical torus models (e.g., borus) as well as a Monte Carlo sampling method, we uncover representative Compton-Thick (CT) AGN candidates with good signal-to-noise ratios. We also analyze the X-ray-to-far-infrared spectral energy distributions (SEDs) and obtain multi-wavelength properties of the large source population in the XMM-SERVS. As a result, we find $\sim$ 50 sources with a high likelihood as CT AGNs, and an increasing CT fraction from low to high redshift. Our CT candidates also tend to show hard X-ray spectral features and dust obscuration in their SED fits, which may shed a light on the contribution of obscuration to the co-evolution of AGNs and host galaxies.

Oral & Poster Programme Abstracts

Tuesday, 27th September 2022

Session 2: What properties of the host galaxies or larger-scale environment affect black-hole growth?

Black hole growth across the population of galaxies and their large-scale environment

James Aird | The University of Edinburgh

Abstract

I will present a retrospective on developments over the last decade in our understanding of where black hole growth occurs across the galaxy population and within the dark matter structure of the Universe. A correlation between the overall black hole accretion and star formation densities of the Universe has been long established, indicating that the growth of black holes is broadly driven by the same physical processes that build up galaxies over cosmic time. However, early studies found that Active Galactic Nuclei (AGN) are preferentially found within the most massive galaxies and suggested that black hole feedback may lead to a delicate balance of AGN vs. star formation. More recently, a better understanding of AGN as hidden monsters and their transient nature over the lifetime of a galaxy has returned us to a picture where the bulk of black hole growth occurs in normal star-forming galaxies and raises the question: are AGN special? The latest results show that AGN are ubiquitous throughout the galaxy population, but their incidence can be enhanced in certain galaxy types. Whether the large-scale environment - vital in determining galaxy properties - has a direct, additional impact on black hole growth remains unclear. As we return to the question of "what drives the growth of black holes?" we must consider the diverse physical mechanisms that can fuel black holes within individual galaxies as they follow a variety of evolutionary paths over cosmic time, as well as the impact of different phases of AGN activity on the galactic environment.

The Origins of Gas Accreted by Supermassive Black Holes: How Do Supermassive Black Holes Get Their Gas?

Ena Choi | Korea Institute for Advanced Study

Abstract

To study the fueling mechanisms of supermassive black holes (SMBH), we examine the origin of gas accreted by $10^{9-9.5}$ $M_{\odot}$ SMBH at $z = 0$ by tracing the history of gas in 10 zoom-in cosmological simulations of massive galaxies. These simulated galaxies have stellar masses of $M_{star} > 10^{11-12} M_{\odot}$ at $z = 0$ with rich major and minor merger histories. We trace the history of gas that central SMBH accretes and classify its origin depending on how it enters the primary halo. Gas that ever belonged to a different galaxy before accretion is defined as (1) 'external', and all other smoothly accreted gas is labeled as (2) 'smooth'. Finally, if the gas is produced by stellar evolution within the primary halo and then accreted to SMBH, we classify it as (3) recycled. We show that the recycled gas from dying stars is the most important source of fuel for the SMBH. The recycled gas from stars in the galaxy's inner region easily collapses toward the galaxy center, triggering the starburst and simultaneously feeding the SMBH. We also show that SMBHs in the massive halos tend to accrete a higher fraction of merger-accreted gas than smooth-accreted gas. Galaxy mergers also play an important role in feeding the SMBH in massive galaxies, but its effect is highly dependent on the galaxy's merger history.

The Incidence of X-ray selected AGN in the nearby Universe

Keir Birchall | University of Leicester

Abstract

Large-scale surveys of the Active Galactic Nuclei (AGN) population performed over the past few decades have highlighted the existence of strong correlations between the central supermassive black hole and their host galaxy. Whilst such samples are incredibly useful, they tend to be incomplete. This skews our understanding of the AGN population as samples consist of largely brighter, more actively accreting objects. Robust measurements of the AGN X-ray luminosity and Eddington ratio distributions at the lowest redshifts would provide a useful benchmark to understand how the AGN population evolved through cosmic time. Thus, in this work, we combined galaxy samples from MPA-JHU with XMM-Newton serendipitous sources to measure the incidence of X-ray selected AGN as a function of galaxy properties in the nearby ($z < 0.35$) Universe, carefully accounting for the incompleteness of the X-ray imaging. Using X-ray selection, we identified 61 AGN in dwarf galaxies, of which 40 are brand new, and 917 in the wider population. Regardless of how the galaxy population was split, the probability of hosting an AGN was well described by a power law and highlighted significant populations at low X-ray luminosities and accretion rates. The fraction of galaxies hosting an AGN was unaffected by stellar mass, staying constant at around 1%, but it increased with redshift, rising from 1% to 10%. When compared to other results, out to z=1, we found the AGN fraction in higher mass galaxies increased significantly, whereas in dwarf galaxies it was constant. Thus, there is evidence of a stellar-mass-dependent distribution of black hole growth rates. Finally, we investigated the effect of star-forming activity, accounting for redshift- and stellar-mass-driven enhancements. We found that the probability of a galaxy hosting an AGN increases with the star formation rate, and AGN activity is twice as likely in star-forming galaxies than their quiescent counterparts.

Constraining the SMBH-halo connection in the local universe

Meredith Powell | Stanford University

Abstract

Characterizing the connection between AGN and their host dark matter halos provides powerful insights on the intertwined stories of structure growth, black hole growth, and galaxy evolution. Here I present constraints on the SMBH mass-halo mass relation at z=0 using the clustering statistics and abundance of hard-X-ray selected AGN from the Swift/BAT AGN Spectroscopic Survey. By forward-modeling AGN activity into cosmological simulations and assuming straightforward relationships between SMBHs, galaxies, and dark matter halos, as well as a universal Eddington Ratio Distribution function, we find that the X-ray luminosity function and clustering on both 1- and 2-halo scales can be reproduced. I also show that degeneracies between different assumptions for the correlation between SMBH mass and halo mass can be broken by investigating AGN clustering trends with black hole mass. We find that a scenario in which SMBH mass correlates with host dark matter (sub)halo mass for fixed stellar mass is preferred by the data over a model absent of this correlation, which would indicate that the halo binding energy is fundamentally connected to the growth of supermassive black holes. Lastly, I will present predictions for higher-redshift constraints on the SMBH-halo connection with future AGN surveys.

Exploring the AGN-ram pressure stripping connection in local clusters

Giorgia Peluso | INAF-OAPD

Abstract

The influence of the large-scale environment on AGN activity is a vibrant field of research. Recent studies reported tentative evidence of a connection between AGN incidence and ram-pressure stripping (RPS) of gas due to the interaction between the intra-cluster medium and the interstellar medium in the galactic disk. The expected link has roots in the fact that the properties of AGN are linked to the conditions of the available gas, which in turn can be strongly affected by RPS. Hydrodynamical simulations showed that RPS can trigger inflows of gas towards the galaxy center by losing angular momentum. Inflows and outflows of gas also accompany often the detection of AGN and strong evidence shows a possible link between the two phenomena, where inflows would trigger the central activity. However, a statistically robust study has never been performed, making it not clear if the link between RPS and AGN is real. We robustly measured, for the first time, the AGN fraction in 115 RP stripped galaxies located in clusters at low redshifts, which represents the widest sample gathered up to now for this purpose. To understand if the RPS enhances the AGN activity, we also computed the AGN fraction in normal galaxies, with similar proprieties of the RP stripped sample, but located in the field and presumably not affected by RP. We found statistical evidence that the AGN-RPS connection does exist: our results show that the AGN fraction rises to 51% when ram-pressure stripping is acting, selecting galaxies with $M_* > 10^10 M_sun$. This fraction is higher than the AGN fraction of 35% in normal galaxies, in the same mass bin. I will talk in more detail about the methods and the results of my analysis, along with the caveat of the methods and the uncertainties associated with the fractions.

A multi-wavelength census of merger-fueled SMBH accretion

Robert Bickley | University of Victoria

Abstract

Major galaxy mergers have long been theorized to contribute to black hole accretion by disrupting the dynamics of the participant systems and funneling gas into their centers. However, never before has this effect been observationally demonstrated in a statistically large and homogeneously selected sample of post-merger (recently coalesced) galaxies. The post-merger epoch is particularly important since it is expected to coincide with the zenith of supermassive black hole activity, but the rarity of post-mergers makes them something of a missing link the merger - AGN sequence. In order to quantify the role of galaxy mergers in growing supermassive black holes, we develop a bespoke convolutional neural network, train it on realistic images of simulated post-merger galaxies, and use it to classify real galaxies imaged in the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS). We visually inspect the resulting classified galaxies and identify a sample of $\sim$700 confirmed post-mergers. Finally, we present the optical, infrared, and radio AGN demographics of the post-mergers, characterizing galaxies' SMBH activity and accretion at arguably the most pivotal moment in their evolution.

Enhanced AGN activity for close galaxy pairs at z=0.5-3

Sean Dougherty | Newcastle University

Abstract

Observations of the nearby universe suggest that galaxy mergers may be able to trigger active galactic nuclei (AGN) even prior to the final coalescence, though there is much controversy surrounding this theory, particularly at high redshifts. To address this question, we use separate methods to assemble large samples of galaxy pairs while accounting for uncertainties in photometric redshifts at $0.5 < z < 3.0$ within extragalactic survey fields observed with some of the highest quality multiwavelength observations. First, we use photometric redshift probability distribution functions and the combined redshift probability function to assign weights for each projected pair. Second, we combine photometric and spectroscopic measurements in a Monte Carlo method to produce samples of paired galaxies. We then incorporate this galaxy pair information with X-ray survey data to calculate the AGN enhancement as a function of pair separation. We find AGN enhancement in galaxy pairs ranging from 50% to 300% across methods for pairs separated by less than 25 kpc with respect to a mass and redshift-matched control sample of isolated galaxies. Finally, we compare our results to both observational studies and simulations addressing these same questions. I will present these results and discuss how subtleties in pair and control galaxy selection can lead to apparent results on the connection between galaxy separation and black hole growth.

Do mergers matter? Luminosity, obscuration and the triggering of AGN

Carolin Villforth | University of Bath

Abstract

The role of mergers in triggering AGN activity has been a subject of significant debate over the last years, while merger triggering was once thought to be responsible for the majority of AGN activity, the picture has become increasingly blurred. It has now become clear that while mergers enhance the probability of galaxies hosting an AGN, they are not the dominant, or even significant, triggering process for the majority of AGN. This leads to the question: are mergers dominant for a specific subset of the AGN population? Two AGN populations that have received a lot of interest are high luminosity AGN and obscured AGN. High luminosity AGN are thought to be associated with mergers due to the large fuel mass required, while obscured AGN are thought to represent an early phase in AGN activity more closely associated with starbursts. Using my own results as well as literature data, I argue that there is no clear trend of merger fraction with AGN luminosity. From a comparison of young compared to X-ray selected AGN using HST data, I will discuss possible differences between obscured and unobscured AGN. I argue that beyond the local universe, merger triggering is not dominant even in luminous and obscured AGN.

Determining the AGN Fraction in Dwarf Galaxy Mergers

Sabrina Stierwalt | Occidental College

Abstract

Measurements of the masses of intermediate mass black holes and the frequency at which we find them in dwarf galaxies can place important constraints on the possible makeup of supermassive black hole seeds. Massive galaxy mergers are thought to inspire black hole grown and trigger AGN activity, so we search a statistically complete sample of 104 interacting dwarf pairs in the local universe for evidence of the presence of intermediate mass black holes. We use multiwavelength diagnostics to assess AGN candidacy, including optical emission spectra, mid-infrared colors from WISE, radio continuum data, and in a subset of cases, X-ray observations. We further separate our sample by environment to control for the effects of a nearby massive galaxy neighbor. Despite the link between galaxy mergers and AGN fueling in more massive galaxies, we do not find evidence that merging dwarf galaxies host a larger fraction of AGN than their non-merging counterparts. In this presentation, we will discuss what the AGN fraction, or lack thereof, in merging dwarfs means in the context of dwarf galaxies known to host black holes and simulations of AGN growth in dwarf-dwarf mergers.

Black Hole Seeds in Dwarf Galaxies: Early Results from DESI

Ragadeepika Pucha | University of Arizona

Abstract

Active Galactic Nuclei (AGN) in low-mass galaxies ($M* \leq 3x10^9$ Msun) are powered by Intermediate-mass Black Holes (IMBHs) that are prime candidates for supermassive black hole (SMBH) seeds. IMBHs remain elusive, as only a few convincing candidates are known to date. Compared to previous surveys, the DESI (Dark Energy Spectroscopic Instrument) survey offers deeper spectra, higher spectral resolution, and a larger number of targets extending to fainter magnitudes ($r < 24.5$ AB). This provides a unique opportunity to extend the search to both lower mass galaxies and higher redshifts. With just one year of DESI data, the number of galaxy spectra has already surpassed that of all existing optical spectroscopic surveys. In this talk, I will present results from early DESI data, where we use optical emission line signatures to accurately identify >1000 new AGN candidates out of ∼200,000 low-mass galaxies. We have already more than doubled the existing census and predict to uncover >10,000 such IMBH candidates by the end of the five-year survey. By estimating BH masses using broad emission lines, we extend the MBH - M* scaling relation to lower masses, providing us with crucial clues about seed formation mechanisms. This new sample will be an important starting point for studying BH demographics, such as BH mass functions as well as BH occupation fraction in low-mass galaxies.

Are black-hole accretion states similar across the mass scale?

Jiri Svoboda | Astronomical Institute of the Czech Academy of Sciences

Abstract

To understand black hole growth, we need to understand the physical processes that drive the accretion of the gas on to the black hole and how they evolve over time. Stellar-mass black holes in X-ray Binaries (XRBs) exhibit extreme spectral state transitions that occur on observable timescales and as a function of accretion rate. A comparison of spectral state changes between stellar and supermassive black holes can inform our understanding of AGN accretion. However, observable timescales for state transitions of AGN are typically not attainable, but can be explored with a large sample of AGN. Here, I will present our analysis of a sample of 3500+ AGN with simultaneous UV and X-ray observations from the XMM-Newton and Neil Gehrels Swift satellites, complemented with radio, optical and infrared data. Our results establish that AGN and XRBs display analogous spectral states, most notably linking the radio emission from the relativistic jet with the energetic emission from the X-ray corona and thermal emission from an accretion disc. I will highlight our unique result demonstrating how the AGN radio morphology correlates with the accretion state change, analogous to the presence of radio jets during a typical XRB outburst. Further, I will present the salient results of our analysis of how different AGN properties, viz. nuclear obscuration, Seyfert type, optical classification are correlated with their observed accretion states, along with their relation to the star formation and stellar masses of their host-galaxies, hinting at the co-evolution of AGN and host galaxy with feeding and feedback.

Linking radio AGN activity to galaxy growth: a super-linear "radio-AGN main sequence"

Ivan Delvecchio | INAF-Astronomical Observatory of Brera

Abstract

It is well established that local ($z < 0.3$) radio AGN are prevalent and brighter in more massive galaxies ($M_* > 10^{10}$ $M_\odot$). However, we still have no clues of such M_* dependence in typical star-forming (SF) galaxies at the "cosmic noon" ($1 < z < 3$). This is key to understanding the role of host-galaxy M_* in shaping radio AGN activity at the peak epoch of cosmic assembly. We leverage deep VLA-COSMOS 3-GHz data to build the luminosity function of radio AGN (RLF) hosted in ($NUVrJ$-selected) SF galaxies at $0.1 < z < 4.5$. For the first time, we decompose the RLF in different M_* bins over the range $9 < \log(M_*/M_\odot) < 12$. The integrated radio AGN luminosity density across SF galaxies is mostly driven by massive galaxies with $10.5 < \log(M_*/M_\odot) < 11$ and peaks at $1 < z < 2$. When averaging this cumulative radio AGN power across *all* M*-selected galaxies at each (M*,z), we obtain a *super-linear* (slope$\sim$1.5) **"radio-AGN main sequence"** that links mean radio AGN power and galaxy M* since z$\sim$3. This behaviour with M_* suggests that **radio AGN activity is strongly enhanced in more massive SFGs**, as compared to galaxy star formation that evolves *linearly* along the "SF main sequence". Intriguingly, this super-linear trend nicely resembles the evolution of X-ray AGN activity with M_*, possibly suggesting a common fueling scenario. We will discuss the broad implications of these results and the missing pieces towards a complete picture of distant BH-galaxy growth.

Discovery of a dominant new population of jet-mode AGN at high redshift

Rohit Kondapally | University of Edinburgh

Abstract

Active galactic nuclei (AGN) can have a significant effect on their host galaxies by regulating their growth or suppressing star formation (known as AGN feedback). A crucial missing piece in galaxy evolution models is to understand the role of AGN feedback in shaping the observed galaxy population from early epochs to the present day. Of particular importance in the life-cycle of massive galaxies and clusters are the jet-mode AGN which display powerful bi-polar radio jets; recurrent feedback from these AGN is believed to keep galaxies 'red and dead' once quenched. However, the cosmic evolution of the jet-mode AGN and their feedback effect remains largely unconstrained beyond z $\sim$ 1. Deep radio surveys offer a unique window into tracing AGN activity over cosmic history. The LOFAR telescope has been undertaking one of the deepest wide-field radio continuum surveys to date: this represents a novel sample to statistically study the growth of AGN activity and feedback across cosmic time. Using a sample of >10,000 AGN, I will present the first robust measurement of the evolution of the jet-mode AGN population out to z $\sim$ 2.5. We discover the existence of a new dominant population of jet-mode AGN hosted by star-forming galaxies at high redshifts that has not previously been observed. I will present an analysis of the host-galaxy properties of these AGN, which shows that the jet-mode AGN in star-forming galaxies are fuelled by a different mechanism compared to their quiescent counterparts. In this talk, I will also model the evolution of the jet-mode AGN and compare these observational results with predictions from latest cosmological simulations to draw conclusions about the evolving role of jet-mode AGN feedback across cosmic time.

A First Look at the Resolved Host Properties of AGN at $3 < z < 5$ with JWST

Dale Kocevski | Colby College

Abstract

I will present the host properties of five X-ray luminous AGN identified at $3 < z < 5$ in the first epoch of imaging from the Cosmic Evolution Early Release Science Survey (CEERS). Each galaxy has been imaged with JWST's Near-Infrared Camera (NIRCam), which provides spatially resolved, rest-frame optical colors and morphologies at these redshifts. We find that the AGN hosts are among the most massive galaxies detected at this redshift range in the current CEERS pointings, even after accounting for nuclear light from the AGN. None of the galaxies show strong morphological disturbances that might indicate a recent interaction or merger event. Notably, four of five hosts have rest-frame optical colors consistent with a quenched or post-starburst stellar population. I will discuss implications of these findings and what they tell us about SMBH growth in massive quiescent galaxies in the early universe.

Fuelling the first black holes: contribution of tidal disruption events

Hamsa Padmanabhan | Université de Genève

Abstract

One of the major unsolved problems in Active Galactic Nuclei (AGN) research involves the fuelling of low-luminosity AGN. A key contribution to the fuelling of AGN at low luminosities could be Tidal Disruption Events (TDEs). We use an empirical approach combining the latest data from X-ray and optical observations of high-redshift galaxies, and the evolution of their central supermassive black holes, to calculate the contribution of TDE to fuelling AGNs as a function of their luminosities. We find that at low redshifts ($z < 1$), a few percent of all AGN with bolometric luminosities $L_{\rm bol} \leq 10^{44} ergs^{-1}$ may be attributable to possible TDEs. However, this fraction can significantly increase at earlier cosmic times, including up to several tens of percent of the population of AGN at $z > 3$. We find that TDEs may comprise a significant fraction of the Compton-Thick (CT) AGN population at $z > 3$. Our findings offer important insights towards unveiling the as-yet poorly understood growth processes of Intermediate Mass Black Holes (IMBHs), whose mergers will constitute the primary gravitational wave event triggers detectable by the forthcoming LISA observatory.

A24 miniJPAS: The 2D properties of X-Ray AGN host galaxies in 56 colors

NISCHAL ACHARYA | Donostia International Physics Center

Abstract

Much has been touted about the relationship between the central supermassive black hole and their host galaxies, active or not. Past and recent studies have shown that the difference between active and non-active galaxies is very minimal when it comes to their global properties and their larger scale environments in the local universe ($z < 0.3$). However, the main difference between these two sets of galaxies is their local environment, and how their stellar properties vary from the center to the outskirts of the galaxies. Here, we use the data from miniJPAS survey with 56 narrow-band and 4 broad-band filters in the optical range to derive the properties of our samples and identify our AGN host galaxies using the data from XMM-Newton survey. And hence, we present the difference between the local (kpc) scale environments of active and non-active galaxies and how these properties drive the growth (or not) of their central supermassive black holes.

A25 Post-Merger Galaxies and AGN in the IllustrisTNG Simulation

Shoshannah Byrne-Mamahit | University of Victoria

Abstract

Observational studies continue to debate the connection between galaxy mergers and AGN, with contrasting conclusions on whether mergers are likely to trigger AGN and whether the majority of AGN are triggered by merger events. This debate is further complicated when considering the effect of AGN selection techniques, AGN luminosity, and redshift. In this work, we study the galaxy merger and AGN connection in cosmological simulations, which allows us to consider a large and diverse sample of galaxy mergers, capturing a range of galactic environments and properties. In this talk, I will present an analysis of AGN and post-merger galaxies at redshift<1 from the IllustrisTNG simulation. This work focuses on the role of galaxy mergers on enhancing supermassive black hole accretion rates, and addresses questions such as: What fraction of mergers enhance black hole accretion rates? Are the enhancements in black hole accretion rate linked to star formation rate enhancements? What fraction of the AGN population have undergone a recent merger event, and how does this depend on luminosity?

A26 The Extragalactic Serendipitous Swift Survey (ExSeSS): survey definition and measurements of the X-ray number counts

Jack Delaney | University of Edinburgh

Abstract

We present new measurements of X-ray source number counts in the 2-10 keV band, providing important constraints on the properties of the AGN population and the distribution of supermassive black hole growth, using the Extra-galactic Serendipitous Swift Survey (ExSeSS) that provides a well-defined sample constructed from observations performed using the Swift X-ray Telescope. The ExSeSS sample consists of 79,152 sources detected in the soft (0.5-2 keV), hard (2-10 keV) or total (0.3-10 keV) energy bands, covering 2086.6 square degrees of sky. Using the new ExSeSS sample we present measurements of the differential number counts of X-ray sources as a function of 2-10 keV flux that trace the population of Active Galactic Nuclei (AGN) in a previously unexplored regime. We show that the assumed X-ray spectral properties have a significant effect on the differential number count measurements. In the hard band, we obtain a good agreement between the ExSeSS measurements and previous, higher energy data from NuSTAR and Swift/BAT when taking into account the varying column density of the ExSeSS sample as well as the X-ray spectral parameters of each of the samples we are comparing to. We also find discrepancies between the ExSeSS measurements and AGN population synthesis models, indicating a change in the properties of the AGN population over this flux range that is not fully described by current models. The ExSeSS sample advances our knowledge of the AGN population and gives us a better understanding of the properties of AGN over this flux range.

A27 Searching for Dual AGN: A Unique Flag of Merger-Driven SMBH Growth

Adi Foord | Stanford University

Abstract

After decades of SMBH observations, the connection between AGN triggering and galaxy mergers remains poorly understood, even though AGN are likely key players in the evolution of massive galaxies. Theoretically, there are many reasons to expect a link between galaxy mergers and the accretion of material onto at least one of the central supermassive black holes. Yet, observationally, contending results have led to uncertainty in whether AGN triggering is dependent on environment. One of the best ways to analyze the possible ties between merger environments and SMBH activity is to study systems with unique observational flags of merger-driven SMBH growth – or, dual AGN. However, there exists no systematic study of the population of dual AGN at redshifts $z > 0.5$. In fact, less than 100 dual AGN are known to date. We are quantifying, for the first time, the dual AGN fraction at high redshift and as a function of redshift, via a large and uniform analysis of AGN between $0.03 < z < 3.5$. By analyzing available data in wide and deep public Chandra surveys, we have placed the first constraint of the dual AGN fraction at both the high-redshift ($1.5 < z < 3.5$) and low-redshift ($z < 0.03$; 7%) regime. Pairing our results with available multi-wavelength data (WISE, HST) we measure how dual AGN activity evolves over cosmic time, and as a function of environment. Lastly, I will highlight capabilities of future high spatial-resolution X-ray observatories, such as AXIS, which will revolutionize the field of dual AGN detectability and our understanding of the role mergers play in AGN triggering.

A28 A Dual QSO at Cosmic Noon

Eilat Glikman | Middlebury College

Abstract

We present the discovery of a dual QSO at z=1.889, a redshift that is in the era known as "cosmic noon" where most of the Universe's black hole and stellar mass growth occurred. The source was identified in Hubble Space Telescope WFC3/IR images of a dust-reddened quasar that showed two closely-separated point sources at a projected distance of 0.26", or 2 kpc. We obtained a spatially-resolved STIS spectrum of the system, covering the visible spectral range, verifying the presence of two distinct quasar components. We also obtained high-resolution radio continuum emission observations with the VLBA at 1.4GHz (21-cm L band) and found two sources coincident with the optical positions. The sources have similar black hole masses, bolometric luminosities, and radio loudness parameters. However, their colors and reddenings differ significantly. The redder quasar has a higher Eddington ratio. We find little evidence in support of lensing for this system. We thus claim this system as a bona-fide dual QSO, which links dust-reddening to galaxy and black hole mergers, opening up a new population in which to search for samples of dual AGN.

A29 The Present and Future of Mid-IR AGN Selection: The Optical Spectroscopic Properties of WISE-Matched AGN

Raphael Hviding | Steward Observatory

Abstract

A complete census of AGNs is necessary to understand the effect of supermassive black hole growth on galaxy evolution over cosmic time. However, obscuration of the nuclear emission and/or host galaxy contamination biases AGN selection. It is therefore crucial to quantify the demographics of AGN selection methodologies especially with upcoming deep and/or high-resolution optical/near-infrared photometric surveys from next generation facilities (Rubin Observatory, Roman Space Telescope, Euclid, JWST, etc.). We explore mid-infrared (mid-IR) AGN selection by completing a systematic spectroscopic and photometric analysis of optically selected galaxies matched to mid-infrared (mid-IR) data from the Wide-Field Infrared Survey Explorer (WISE). We have examined over 400,000 galaxies from the Sloan Digital Sky Survey (SDSS) to break down WISE color space by optical spectroscopic properties culminating in the first mid-IR AGN selection criterion defined by solely using optical spectroscopic properties. Our selection is not only an improvement of 50% in the completeness of targeting spectroscopic AGNs with WISE, but critically targets a less luminous population of AGNs, with on average lower [O III] luminosities by 30% compared to typical WISE color-color selections. In follow-up work, we have employed machine learning techniques to analyze deeper optical photometry from Hyper Suprime-Cam (HSC) matched to WISE to quantify what kinds of AGN are systematically under-targeted by current optical surveys such as SDSS. Our results provide insight for the future of mid-IR AGN selection matched to the next generation of optical/near-infrared photometry towards building a more complete census of AGN activity at lower luminosities or higher levels of obscuration.

A30 Massive Black Hole Growth in the Local Universe - the BASS Multi-wavelength Perspective

Michael Koss | Eureka Scientific

Abstract

Accreting supermassive black holes (SMBHs) are among the most luminous sources of radiation in the Universe and are thought to play an important role in the evolution of their host galaxies. The BAT AGN Spectroscopic Survey (BASS) is designed to provide a highly complete census of the key physical parameters of growing SMBHs, including their radiative outputs, black hole masses, accretion rates, and line-of-sight gas obscuration, as well as the distinctive properties of their host galaxies (e.g., star formation rates, masses, and gas fractions). BASS uses an all-sky survey of the brightest and most powerful hard X-ray emission in the sky that can trace even highly obscured AGN, and then following them up with a multitude of observations carried out with large allocations of time on advanced facilities (including VLT, Keck, Gemini, Chandra, NuSTAR, VLA, ALMA, etc.). As such, BASS provides a crucial high-resolution, high-sensitivity, low-redshift benchmark for studying the cosmic evolution of SMBHs, anchoring narrow and deep surveys that focus on higher redshifts. I will review recent results from the BASS DR2, a 9 paper ApJ special issue with 1450 new optical and NIR spectra released for the first time. I will review its implications for answering fundamental questions about SMBH growth and its links to host galaxy evolution and feedback in the local universe.

A31 A new Bayesian multi-wavelength approach to constrain physical properties and space density of X-ray AGNs

Brivael Laloux | Durham university / National Observatory of Athens

Abstract

Understanding the accretion and evolution of supermassive black holes in the Universe requires complete demographical studies of Active Galactic Nuclei (AGNs) to estimate, at any given time, the space density of black holes that experience a growth event. In this approach, obscured AGNs are a significant challenge as they are hidden behind clouds of dust and gas and are hard to identify observationally. Accounting for these systems, especially in the case of very dense obscuring material (often referred to as Compton thick), is not straightforward. We propose a new Bayesian approach for characterising the level of obscuration of AGNs in deep extragalactic survey fields. This approach uses multiwavelength priors on the bolometric AGN luminosity to guide X-ray spectral analysis and yield improved constraints on the physical properties of the corresponding AGNs. We apply this method to the multiwavelength observations in the Chandra COSMOS-Legacy field to provide a new sample of heavily obscured and Compton thick AGNs. This is further combined with an accurate characterisation of the X-ray selection function of the Chandra COSMOS-Legacy survey to estimate in a non-parametric manner the AGN X-ray luminosity function at different levels of line-of-sight obscuration, parametrised by hydrogen column density, N_H. Our analysis provides new constraints on the Compton thick AGN fraction ($N_H > 10^{24}$cm^{-2}) out to $z \sim 2$ and find that our results, based on prior-augmented X-ray spectral analysis, deviate from popular X-ray luminosity functions in the literature. Our results argue for new estimates of the AGN luminosity function evolution using the proposed Bayesian multi-wavelength approach.

A32 Major Mergers Do Not Trigger the Majority of Less Luminous AGN at Cosmic Noon

Erini Lambrides | NASA-Goddard

Abstract

Major mergers are commonly invoked as the dominant triggering mechanism of AGN across large spans of cosmic time; yet, observational and theoretical evidence supporting the ubiquity of this scenario is mixed. In particular, less luminous AGN, which make up the bulk of the AGN population across many epochs, have the most mixed results with regards to the major-merger paradigm. If the AGN-merger paradigm is true, we expect galaxy mergers to coincide with black hole accretion during a heavily obscured AGN phase ($N_H > 10^{23}$ per cm^2). In this talk, I will discuss the uncovering of the largest, low-to-moderate luminosity heavily obscured AGN sample at cosmic noon. These objects were previously misclassified as un-obscured AGN, and I will justify why these classes of AGN are the ideal sources for testing the major-merger paradigm as a dominant AGN triggering method. I also discuss our results on the combination of deep color Hubble Space Telescope imaging and a novel method of human classification to test the merger-AGN paradigm prediction that heavily obscured AGN are strongly associated with galaxies undergoing a major merger. The results show that there is no statistically significant evidence that obscured AGN at cosmic noon are predominantly found in merging/post-merging systems. These findings indicate other triggering mechanisms must play a significant role in the AGN phenomenon and thus galaxy evolution at this cosmic epoch.

A33 Feeding and feedback in Post-starburst galaxies

Lauranne Lanz | The College of New Jersey

Abstract

A major open question in galaxy evolution is the activity and role of AGN in the transition from star-forming to quiescence. Post-starburst galaxies are the logical laboratory in which to investigate this question. We recently examined the X-ray luminosity of a sample of post-starburst galaxies using a forward-modeling analysis to constrain their properties based on their weak but significantly detected emission. We find that many of these galaxies are consistent with a lower-luminosity AGN present in high fractions. I will discuss both the methodology used to constrain their parameters and the implication of their luminosities on the role of AGN activity in post-starburst galaxies.

A34 Mergers Dominate the Host Galaxies of Low-z LoBAL QSOs: Insights from HST

Mariana Lazarova | University of Northern Colorado, USA

Abstract

The ultrafast outflows characteristic of broad absorption line (BAL) QSOs suggest that, in those systems, we might be observing AGN-driven kinetic feedback capable of affecting the growth of the host galaxy. Particularly relevant to this picture might be low-ionization BAL QSOs (LoBALs) at low redshifts because anecdotal studies find that they might be connected to major mergers and ultra-luminous infrared galaxies. We take a detailed look at the host galaxy morphologies and SEDs of a complete, volume-limited sample of optically-selected LoBALs at $0.5 < z < 0.6$. Their infrared luminosities and star formation rates do not suggest they are different from typical type-1 QSOs. After correcting for the AGN contribution to the FIR SED, LoBALs show levels of star formation similar to those of type-1 QSOs. However, the observations of their host galaxies with HST/WFC3 reveal apparent signs of recent or on-going tidal interaction in 68% of the sample, which is in contrast to recent work on QSO hosts showing merger fraction of less than 20-25%. The mergers in our sample represent various stages of the merger process: from settled morphologies with extended low surface-brightness tidal tails to double nuclei (in at least 41% of the sample). Our results favor an evolutionary explanation for the emergence of low-z LoBALs, in which quasar-level accretion during various stages of the merger process is associated with the observed fast outflows, as suggested by some simulation studies. We discuss important differences between LoBALs and FeLoBALs, and demonstrate that the traditional BALs selection criteria would have excluded all but one of the mergers in this sample.

A35 SMBH accretion rates distributions using the miniJPAS survey

Iván López | Unibo-INAF

Abstract

An unbiased distribution of AGN accretion rates can help us to understand better the relationship between the super-massive black hole and their host galaxies. However, measurements of these rates are hard to estimate across cosmological times. With the Javalambre-Physics of the Accelerating Universe Astrophysical Survey (J-PAS) and their 54 narrow filters, we can obtain pseudo-spectra using the photometric fluxes with a deep sky coverage. These data, combined with observations in other wavelengths can help us to obtain a more robust estimate of AGN accretion rates. Using the preview data of JPAS (miniJPAS), we compiled a catalog of 347 X-ray sources with confident spectral redshift and a miniJPAS detection. We added fluxes in other wavelengths and we fitted the spectral energy distribution (SED) using Cigale to obtained stellar masses, star formation rates, and AGN bolometric luminosities. We also fitted the available spectra to estimate the black hole masses from broad lines. We studied the relationship between these physical parameters and the observational selection effects in our sample. We forecast the application of this methodology with full J-PAS, combined with eROSITA X-ray fluxes to obtain AGN luminosity functions and accretion rate distributions to the lowest luminosities.

A36 Identifying active galactic nuclei via brightness temperature with sub-arcsecond International LOFAR Telescope observations

Leah Morabito | Durham University

Abstract

Identifying active galactic nuclei (AGN) and isolating their contribution to a galaxy's energy budget is crucial for studying the co-evolution of AGN and their host galaxies. Brightness temperature (T_b) measurements from high-resolution radio observations are widely used to identify AGN, but require $\sim$milli-arcsec resolution at GHz frequencies. In this talk, I will present a study using new sub-arcsecond imaging at 144 MHz with the International LOFAR Telescope (ILT) to identify AGN using T_b in the Lockman Hole field. We use ancillary data and SED fitting results to investiage the identified AGN, finding that 83 percent of sources have AGN classifications from SED fitting and/or photometric identifications. This increases to 91 percent when considering only sources identified using peak flux density instead of total. Infrared colour-colour plots show AGN classified as star-forming galaxies (SFGs) by SED fitting are likely composite sources. Comparing the sub-arcsecond resolution ILT image with a 6 arcsec resolution ILT image, the ratio of detected to detectable sources, as a function of flux density, splits below $\sim$5 mJy for all sources versus those identified as AGN, implying a mixture of SFGs and AGN at low flux densities. Over half of radio-excess sources, but only 12 percent of SFGs and 22 percent of radio-quiet AGN are identified via T_b. We separate the radio emission from star-formation and AGN in unresolved, T_b-identified AGN and find the AGN fraction is 0.47 ± 0.17. Overall the non-radio excess AGN populations in this sample show evidence for having a variety of different radio emission mechanisms, which can provide different pathways for AGN and galaxy co-evolution.

A37 Exploring the Interplay Between Merging Galaxy Clusters and Radio-AGN out to z$\sim$1

Emily Moravec | Green Bank Observatory

Abstract

In the last 10 years, large-scale environments, such as galaxy clusters, have shown to affect the characteristics, triggering, and growth of AGN. By probing progressively higher redshifts, where radio-AGN in particular are more populous and clusters are still assembling, we can study the impact of the large-scale cluster environment on the evolution of AGN. To do this, I will first present the results of a deep, multi-wavelength study (PAN-STARRS, Spitzer, LOFAR Two-metre Sky Survey 150 MHz, VLA 1.4 GHz, and GBT MUSTANG-2 90 GHz) of the radio-AGN population in MOO J1507+5137, a system where the radio activity appears to be linked to the dynamical state of the cluster. Specifically we find that the merger phase dramatically enhances the radio activity. In light of this work, an open question is whether cluster-cluster mergers ubiquitously trigger radio-AGN activity and how this particular large-scale environment affects black hole fueling and accretion. To investigate this, I will present the results of two studies that compare the radio-AGN activity between merging and non-merging environments. The first compares the radio-AGN activity of 12 merging and 7 relaxed clusters at z$\sim$1, an epoch during which the number of radio-AGN in clusters peaks. The second compares the radio-AGN activity of 8 merging and 25 relaxed clusters at low-redshift using LoTSS, FIRST, and VLASS data. With these two studies in tandem, we will be able to better understand how large-scale environment impacts AGN and black hole evolution.

A38 The relation between black-hole growth and host-galaxy compactness among star-forming galaxies

Qingling Ni | The University of Edinburgh

Abstract

Recent studies show that a universal relation between black-hole (BH) growth and stellar mass (M*) or star formation rate (SFR) is an oversimplification of BH-galaxy co-evolution, and that morphological and structural properties of host galaxies must also be considered. Particularly, a possible connection between BH growth and host-galaxy compactness was identified among star-forming (SF) galaxies. Utilizing galaxies in the COSMOS field, we perform systematic partial-correlation analyses to investigate how sample-averaged BH accretion rate (BHAR) depends on host-galaxy compactness among SF galaxies, when controlling for morphology and M* (or SFR). The projected central surface-mass density within 1 kpc, $\Sigma 1$, is utilized to represent host-galaxy compactness in our study. We find that the BHAR-$\Sigma 1$ relation is stronger than either the BHAR-M* or BHAR-SFR relation among SF galaxies, and this BHAR-$\Sigma 1$ relation applies to both bulge-dominated galaxies and galaxies that are not dominated by bulges. This BHAR-$\Sigma 1$ relation among SF galaxies suggests a link between BH growth and the central gas density of host galaxies on the kpc scale, which may further imply a common origin of the gas in the vicinity of the BH and in the central $\sim$ kpc of the galaxy. This BHAR-$\Sigma 1$ relation can also be interpreted as the relation between BH growth and the central velocity dispersion of host galaxies at a given gas content, indicating the role of the host-galaxy potential well in feeding BHs.

A39 Spotted: Dual Broad Line AGNs Identified in Two Minor Galaxy Mergers?

Ryan Pfeifle | NASA Goddard Space Flight Center; George Mason University

Abstract

Theoretical studies predict that the most significant growth of supermassive black holes occurs in late-stage mergers and coincides with the manifestation of dual active galactic nuclei (AGN), and both major and minor mergers are expected to be important for dual AGN growth. Though minor mergers are the dominant form of galaxy merging, only two dual AGNs have been identified in minor mergers. No systematic searches for dual AGNs in minor mergers have been performed. As part of a larger multi-wavelength program to identify and characterize merger driven AGNs in the local Universe, we have serendipitously discovered two candidate dual AGNs that reside in minor mergers of $\sim$1:10 and $\sim$1:30 mass ratios, respectively. Already obtained spectroscopic observations show a series of broad and narrow emission lines in the primary nuclei of each merger while only a broadened and prominent H-alpha complex is observed in the secondary nuclei. However, the widths of the broad H-alpha lines in the primary and secondary nuclei do not match, i.e., they are unlikely to be the result of cross contamination from the more massive progenitor in the minor merger. These suggest that not only do both nuclei in each minor merger pair host an AGN, but that each of the AGNs in both minor-merger systems show evidence of a broad line region (BLR). We will demonstrate that competing scenarios (such as a foreground star, or background AGN) can be ruled out. These targets would not only be the first dual BLR pairs in the local Universe, but the first such identified in minor mergers in the local Universe. These findings are likely to provide observational constraints on the observability of dual AGNs in highly unequal mass mergers in the local Universe.

A40 AGN in dwarfs: does the environment matters?

Malgorzata Siudek | IFAE, Barcelona

Abstract

The statistical power of the VIPERS survey which observed ∼90,000 galaxies and the wealth of auxiliary data allowed us to select a few hundreds of AGN in dwarf galaxies at $0.5 < z < 0.9$ to study their environmental properties. The environment is found to play a significant role in shaping the star formation rate of both low-mass and massive galaxies at $z < 1$. Investigating environmental effects on triggering AGN activity is particularly important in dwarf galaxies, as they are the most abundant galaxies in the Universe and the building blocks of massive galaxies. Determining the role of the environment is crucial not only for studies of galaxy formation and evolution but also for understanding whether AGN in today's dwarf galaxies is the relics of the early Universes seed black holes. In my talk, I explore the relation between low-mass galaxies (no)hosting AGNs and their environment, revealing that dwarf galaxies at intermediate redshift reside in the same environments independently of hosting or not AGN.

A41 Observational Evidence for a Transition from Offset to Dual AGN Predominance in Late Stage Mergers

Aaron Stemo | Vanderbilt University

Abstract

Galaxy mergers are key events in the process of galaxy evolution, possibly triggering enhanced star formation and supermassive black hole (SMBH) growth that peaks at separations under 20 kpc. With enhanced SMBH growth predicted, one or both SMBHs may become observable as active galactic nuclei (AGN) during this phase; these are defined as offset and dual AGN, respectively. Since offset and dual AGN are unique to this period of heightened activity in galaxy mergers, finding and studying them can give insight into the mechanisms of SMBH - galaxy coevolution. However, statistical studies of offset and dual AGN have been limited due to the small number of known systems. To better understand these systems, I examined 173 offset and dual AGN systems from the ACS-AGN Merger Catalog with archival high-resolution Chandra observations using BAYMAX, a Bayesian analysis tool. Preliminary work has determined 10 to be dual AGN and 103 to be offset AGN. Analysis of these samples seems to show that dual AGN prefer the most major of merges, and that in the 1-20 kpc separation phase, there is a shift from offset AGN dominance at larger separations to dual AGN dominance at the smallest separations.

A42 Radio Galaxies in the era of the SKA: Predictions from Cosmological Simulations

Nicole Thomas | Durham University

Abstract

The relativistic jets emitted from radio loud active galactic nuclei (RLAGN) play a key role in the evolution and quenching of massive galaxies, and while theoretical models have become increasingly useful in understanding this role, the processes describing the accretion and feedback mechanisms of the central supermassive black holes are still poorly defined. The SIMBA cosmological simulation is unique in its two-mode black hole accretion and physically motivated feedback prescriptions which provides a simple yet unique approach to defining two sub-classes of RLAGN, namely high- and low excitation radio galaxies (HERGs and LERGs), as well as a providing platform to investigate the differences in their global and environmental properties. I will present results of the properties of radio galaxies predicted by SIMBA and briefly introduce MIGHTEE, an SKA precursor survey, which aims to probe the accretion and feedback processes of AGN and star formation out to cosmic noon. I will present a comparison of SIMBA predictions with preliminary results of the MIGHTEE radio galaxy population. I will then detail ongoing plans to incorporate high resolution LOFAR observations and semi-analytic models to improve our theoretical understanding of RLAGN and disentangle the physical mechanisms driving radio emission from star formation and black hole accretion processes.

A43 Black Hole Mapper in SDSS-V

Benny Trakhtenbrot | Tel Aviv University

Abstract

A44 ALMA Lensing Cluster Survey: Properties of Submillimeter Galaxies Hosting X-ray Detected Active Galactic Nuclei

Ryosuke Uematsu | Kyoto University

Abstract

We report the multiwavelength properties of submillimeter galaxies hosting X-ray detected active galactic nuclei (AGNs) from the ALMA Lensing Cluster Survey (ALCS), an extensive survey of well-studied lensing clusters with ALMA, covering an area of 134 arcmin^2 over 33 clusters with a 1.2 mm flux-density limit of $\sim$70 μJy (1σ). Utilizing the archived data of Chandra, we identify three AGNs at z=1.06, 2.09, and 2.84 among more than 100 submillimeter galaxies ($> 5\sigma$) in the ALCS. The X-ray spectral analysis shows that two AGNs are not significantly absorbed and one is moderately absorbed. We have performed SED modelling of X-ray to millimeter photometries with the latest version of Code Investigating GALaxy Emission (CIGALE) by Yang et al. 2022. We find that our sample shows both high mass accretion rates (intrinsic 0.5-8 keV X-ray luminosities of $\sim 10^{44-45}$ erg/s) and star-forming rates ($\gtrsim$100Msun). This demonstrates that a wide-area survey with ALMA and Chandra can selectively detect intense growth of both galaxies and supermassive black holes at high-z universe.

A45 TRINITY: Self-Consistently Modeling the Dark Matter Halo–Galaxy–Supermassive Black Hole Connection from $z = 0$–10

Haowen Zhang | University of Arizona

Abstract

We present TRINITY, a flexible empirical model that self-consistently infers the statistical connection between dark matter haloes, galaxies, and supermassive black holes (SMBHs). TRINITY is constrained by galaxy observables from $0 < z < 10$ (galaxies' stellar mass functions, specific and cosmic SFRs, quenched fractions, and UV luminosity functions) and SMBH observables from $0 < z < 6.5$ (quasar luminosity functions, quasar probability distribution functions, active black hole mass functions, local SMBH mass–bulge mass relations, and the observed SMBH mass distributions of high redshift bright quasars). The model includes full treatment of observational systematics (e.g., AGN obscuration and errors in stellar masses). From these data, TRINITY infers the average SMBH mass, SMBH accretion rate, merger rate, and Eddington ratio distribution as functions of halo mass, galaxy stellar mass, and redshift. Key findings include: 1) the normalization and the slope of the SMBH mass–bulge mass relation increase mildly from $z = 0$ to $z = 10$; 2) AGNs show downsizing, i.e., the Eddington ratios of more massive SMBHs start to decrease earlier than those of lower-mass objects; 3) The average ratio between average SMBH accretion rate and SFR is $\sim 10^{-3}$ for low-mass galaxies, which are primarily star-forming. This ratio increases to $\sim 10^{-1}$ for the most massive haloes below $z \sim 1$, where star formation is quenched but SMBHs continue to accrete. 4) SMBH have narrower Eddington ratio (η) distributions and higher average η towards higher redshifts. At z$\sim$6, AGN luminosity functions are dominated by objects with $0.1 < \eta < 1$. 5) the typical host halo masses of bright quasars ($L_{\rm bol} > 5 \times 10^{45}$ erg/s) remain around $10^{12} M_\odot$ from $z = 0 - 10$, and the host halo mass distribution is broader at lower redshifts.

R-A5 Reverberation mapping quasars with DESI

Rahma Alfarsy | University of Portsmouth

Abstract

Reverberation mapping of quasars is a technique used to measure the radius of broad line regions (BLRs) by detecting the time lag between the accretion disk continuum and the broad line flux variations. This radius can be combined with the velocity of the BLR gas deduced from the broad line width to calculate the virial mass of the central supermassive black hole. Reverberation mapping brings light to the inner structure and kinematics of AGN that are not spatially resolvable. Moreover, a tight relation between the radius of the BLR and the luminosity of the quasar has been observed. Since this relation derives from the comparable astrophysics of quasars and is redshift independent, it offers quasars up as a promising candidate for a high redshift standardisable candle. This cosmological application of quasars will allow us to extend the Hubble diagram to high redshifts and therefore bridge the gap between high and low redshift measurements of the Hubble constant as well as allowing us to test cosmological models. DESI is forecasted to observe millions of quasars. This will overcome the statistical barriers previously encountered in reverberation mapping and cosmological analyses. This project sets out to determine the feasibility of reverberation mapping with DESI data combined with other available spectroscopic and photometric data using a composite lags method.

R-A6 Understanding the role of the most obscured black hole growth with NuLANDS

Peter Boorman | Astronomical Institute of the Czech Academy of Sciences

Abstract

Most mass is accreted onto supermassive black holes behind thick columns of gas and dust. An accurate assessment of the abundance of the most obscured "Compton-thick" AGN provides important insights into the composition and structure of the circum-nuclear environment, as well as the growth of supermassive black holes and galaxies across cosmic time. Current estimates of the heavily obscured AGN fraction are ill-constrained, ranging over ∼10-60% of the entire population, and it remains unclear whether this wide range is driven by selection effects, inadequate sample sizes, luminosity/accretion rate dependences, computational struggles with exploring complex parameter spaces or something else entirely. An important handicap of previous works has been the inability to effectively select heavily obscured AGN with approximately equal efficacy relative to the (often brighter) less-obscured AGN population — i.e. to mitigate biases associated with Compton-thick obscuration. To investigate such issues, we present NuLANDS — one of the largest NuSTAR legacy surveys, based on combined mid-to-far infrared selection and broadband X-ray constraints, aimed at constructing an obscuration-unbiased census of AGN in the local Universe. In this talk, I will overview the unique selection strategy of NuLANDS and highlight the importance of isotropic selection in eliminating line-of-sight obscuration biases. I will then present the NuLANDS obscuring column density distribution, showing a Compton-thick fraction that is consistent with the most recent estimates from Cosmic X-ray Background synthesis modelling. NuLANDS thus marks a major step in completing the census of AGN accretion activity in our cosmic backyard, and will provide a testbed for future surveys of more distant cosmic epochs with next-generation instruments such as JWST and SRG, aiming to understand AGN growth with minimal obscuration biases.

R-A7 Population evolution with Chandra, XMM, NuSTAR and now eROSITA: from bright unobscured to faint Compton-thick AGN and back

Johannes Buchner | MPE

Abstract

I will reflect on the last decade of investigations of the bulk AGN population and its evolution, the black hole mass accretion history, obscured and Compton-thick fractions, obscurer and reflection models, as probed by Chandra, XMM-Newton, and NuSTAR. These are complemented by new insights from eROSITA. eROSITA demonstrated its unprecedented capabilities for mapping the X-ray sky with a deep 140deg^2 survey taken within just four days. This enables the study of previously poorly sampled AGN populations, including the local Universe and luminous quasars. An outlook will enumerate currently unresolved challenges on characterizing host galaxies of both type 2 and type 1 quasars. Only with progress on these challenges, galaxy models invoking black hole feeding and feedback can be differentiated.

R-A8 Cosmic evolution of AGN incidence in massive clusters

Iván Muñoz Rodríguez | National Observatory of Athens & University of Southampton

Abstract

A major challenge in modern astrophysical research is the physical description of the growth of super-massive black holes that inhabit in the center of galaxies. Although different mechanisms that promote accretion events onto the black holes have been proposed, there is still an intense debate on their relative importance. For example, if the environment has a significant impact (or not), it is still not clear. In this contribution I will present new results on the role of small-scale environment ($<$1Mpc) in the activation of super-massive black holes. A novel semi-empirical model of AGN and galaxies in the Universe will be presented, which is carefully engineered to address this issue. Using a forward-modeling approach, I will compare the predictions of the semi-empirical model with observational results on the fraction and radial distribution of X-ray selected AGN in massive clusters of galaxies out to redshift z$\sim$1.5. I will discuss these results in the context of physical mechanisms that operate in dense environments and modulate the triggering of accretion events onto the super-massive black holes of galaxies. Evidence for variations of the incidence of AGN in galaxy clusters as a function of redshift will also be presented and discussed.

Oral & Poster Programme Abstracts

Thursday, 29th September 2022

Session 3: What fuels the rapid growth of the most massive (and also the first) black holes?

The assembly of the most massive black holes

Melanie Habouzit | ITA (Heidelberg University) and MPIA (Max Planck)

Abstract

The discovery of extremely luminous but rare quasars when the Universe was less than a billion years old has raised fundamental questions about the formation and growth of massive black holes (BHs). How did these first BHs grow so large so fast? Even if formed as massive seeds, quasars must have sustained a high duty cycle during their lifetime. In this talk, I will review our current understanding of the physical processes responsible for driving the assembly of such objects (e.g., accretion, episodes of super-Eddington accretion, BH mergers, special environments). I will present the most recent observational results on high-redshift quasars and their environments, and describe the exciting discoveries that we expect in the near future from current and future telescopes (e.g. JWST). On the theoretical side, I will focus on what we have learned from cosmological simulations of different types. Over the last decade, they have become indispensable to face the challenge of the growth of BHs and their co-evolution with galaxies.

Comprehensive Multiwavelength Studies of Local U/LIRGs observed with NuSTAR and/or Swift/BAT

Satoshi Yamada | RIKEN

Abstract

We perform a systematic X-ray spectroscopic analysis of 57 local ultra/luminous infrared galaxy (U/LIRG) systems (containing 84 individual galaxies) observed with NuSTAR and/or Swift/BAT. Combining soft X-ray data obtained with Chandra, XMM-Newton, Suzaku and/or Swift/XRT, we identify 40 hard (>10 keV) X-ray detected AGNs and constrain their torus parameters with the X-ray clumpy torus model XCLUMPY. Among the AGNs at z $<$ 0.03, for which sample biases are minimized, the fraction of Compton-thick (NH $> 10^{24}$ cm^{-2}) AGNs reaches ∼64% in late mergers, while ∼24% in early mergers, consistent with the tendency reported by Ricci+17 and Ricci+21. We find that the bolometric AGN luminosities derived from the infrared data increase, but the X-ray to bolometric luminosity ratios decrease, with merger stage. The X-ray weak AGNs in late mergers ubiquitously show massive outflows at sub-pc to kpc scales. Among them, the most luminous AGNs ($L_{bol,AGN} \sim 10^{46}$ erg/s) have relatively small column densities of $< 10^{23}$ cm^{-2} and almost super-Eddington ratios ($\lambda_{Edd} \sim 1.0$). Their torus covering factors (CF$^{(22)} \sim 0.6$) are larger than those of Swift/BAT selected AGNs with similarly high Eddington ratios. These results suggest a scenario that, in the final stage of mergers, multiphase strong outflows are produced due to chaotic quasi-spherical inflows and the AGN becomes extremely X-ray weak and deeply buried due to obscuration by inflowing and/or outflowing material.

The Feeding Habits of SMBHs in Extremely Luminous Obscured Quasars at Cosmic Noon and Beyond

Tanio Diaz Santos | Institute of Astrophysics - FORTH

Abstract

In this talk I will report on the results from an ALMA pilot survey of a sample of 7 extremely luminous (EL; Lbol $\geq 10^{14}$ Lsun), hot, dust-obscured galaxies (Hot DOGs) at redshifts $z \sim 3$ - 4.6. Hot DOGs are thought to be mainly powered by heavily obscured super-massive black hole (SMBH) accretion, at rates close or higher than the Eddington limit. Observations of the fine-structure [CII] emission line at 158um in this obscured quasar sample have revealed their host galaxies have highly diverse kinematics: from barely rotating structures, to resolved hosts with ordered velocity fields, to complex, disturbed systems that are likely the result of ongoing mergers. In contrast, all sources display large line-velocity dispersions, FWHM[CII] $\geq$ 500 km s^{-1}, which are, on average, larger than optically and IR-selected quasars at similar or higher redshifts. I will argue that one possible hypothesis that explains the lack of a common velocity structure, the systematically large dispersion of the ionized gas, and the presence of nearby companion galaxies around most of these obscured quasars, may be that the EL Hot DOG phase could be recurrent, instead of a single, major merger event, as it is commonly understood in the nearby Universe in regards to the origin of ultra-luminous infrared galaxies. At high redshift, the dynamical friction from the frequent in-fall of neighbor galaxies and gas clumps, along with the subsequent quasar feedback, would contribute to the high turbulence of the gas within the Hot DOG host in a process that could potentially trigger not a single, continuous EL, obscured event –but instead a number of recurrent, shorter-lived episodes of strong SMBH growth as long as external accretion continues.

Dusty quasars eject star-forming gas from galaxies at cosmic noon

Hannah Stacey | Max Planck Institute for Astrophysics

Abstract

The canonical picture of galaxy evolution invokes strong feedback from active galactic nuclei (AGN) to reduce the star formation efficiency of massive galaxies. This process can explain their observed scaling relations, which were already established by cosmic noon ($z = 2 - 3$). However, the physical channels that allow energy and momentum released on sub-pc scales to affect gas on galactic scales are largely unconstrained. In this presentation, I show a direct link between quasar dust-reddening and molecular outflows at $z \sim 2.5$. By examining the dynamics of warm molecular gas in the inner regions of galaxies, we detect outflows from within the galactic bulges (~ 100 pc)) with short timescales of 0.05 Myr that are due to ongoing energy output from the AGN. We observe outflows only in systems where quasar radiation pressure on dust is sufficiently large to expel their obscuring column densities, indicating that radiative feedback regulates gas in the nuclear regions of galaxies. This is in agreement with theoretical models that predict radiation pressure on dust in the vicinity of the black hole is a major driving mechanism of galactic-scale outflows of cold gas. Our findings show that quasar radiation ejects star-forming gas from nascent stellar bulges at velocities comparable to those seen on larger scales in ionised gas, and that molecules survive in outflows even from the most luminous quasars. I will detail how our results can inform observational tests of multi-phase AGN feedback and implementations of feedback in next-generation cosmological simulations.

eROSITA and WISE view of dust-obscured AGN at $z < 4$

Yoshiki Toba | National Astronomical Observatory of Japan

Abstract

Dust-obscured AGN is thought to be an important phase in the course of galaxy-SMBH co-evolution in which SMBH and its host galaxy are actively growing behind a large amount of gas and dust. The combination of X-ray and mid-IR observations provides an effective way to search for dust-obscured AGN and its physical properties. In this talk, we present the physical properties of mid-IR galaxies/AGN at $z < 4$ in the 140 deg^2 fields observed by SRG/eROSITA using the PV phase program (eFEDS). By cross-matching the WISE 22 μm (W4)-detected sample and the eFEDS X-ray point-source catalog, we find that 693 galaxies/AGN are detected by eROSITA. We have compiled a multi-wavelength dataset extending from X-ray to far-IR wavelengths. We have also performed (i) an X-ray spectral analysis, (ii) SED fitting using X-CIGALE, (iii) 2D image-decomposition analysis using Subaru Hyper Suprime-Cam (HSC) images, and (iv) optical spectral fitting with QSFit to investigate the AGN and host galaxy properties. For 7,707 WISE 22 μm objects that are undetected by eROSITA, we have performed an X-ray stacking analysis to examine the typical physical properties of these X-ray faint and probably obscured objects. We find that (i) 82% of the eFEDS–W4 sources are classified as X-ray AGN with $\log L_{\rm X} > 42$ erg s^{-1}; (ii) 67% and 24% of the objects have $\log (L_{\rm IR}/L_{sun}) > 12$ and 13, respectively; (iii) the relationship between $L_{\rm X}$ and the 6 μm luminosity is consistent with that reported in previous works; and (iv) the relationship between the Eddington ratio and $N_{\rm H}$ for the eFEDS–W4 sample and a comparison with a model prediction from a galaxy-merger simulation indicates that approximately 5.0% of the eFEDS–W4 sources in our sample are likely to be in an AGN-feedback phase, in which strong radiation pressure from the AGN blows out the surrounding material from the nuclear region.

Why is colour special? Identifying fundamental differences between red and blue quasars

Victoria Fawcett | Durham University

Abstract

An important fraction of quasars are red at optical wavelengths, indicating (in the vast majority of cases) that the accretion disc is obscured by a column of dust which extinguishes the shorter-wavelength blue emission. In recent work, fundamental differences have been found in the radio properties of SDSS optically selected red quasars, which cannot be explained with a simple viewing angle hypothesis (e.g., Klindt et al. 2019, Fawcett et al. 2020, Rosario et al. 2020). In our work, we use VLT/X-shooter spectroscopy of a sample of red and typical quasars to gain insight into these differences. We confirm that dust reddening is the main cause of the red colours and explore the emission line properties of our sample. We confront our spectra against accretion disc models and confirm that red quasars are powered by standard thin-disc accretion once corrected for dust extinction. These results suggest that dusty winds could be driving the fundamental differences in red quasars, and so they may represent an important phase in galaxy evolution. Using DESI spectra, we can now push to more extinguished, lower luminosity systems, which will test whether these results extend to more extreme reddened systems.

Physical Models for the Clustering of Obscured and Unobscured Quasars

Grayson Petter & Kelly Whalen | Dartmouth College

Abstract

Clustering measurements of obscured and unobscured quasars show that obscured quasars reside in more massive dark matter halos than their unobscured counterparts. These results are inconsistent with simple unified (torus) scenarios but might be explained by models in which the distribution of obscuring material depends on Eddington ratio or galaxy stellar mass. We test these possibilities by constructing simple physical models to compare to observed active galactic nucleus populations. We present results that show previously observed relationships between obscuration and Eddington ratio or stellar mass are not sufficient to reproduce the observed quasar clustering results for obscured and unobscured populations while maintaining the observed fraction of obscured quasars. This work suggests that evolutionary models, in which obscuration evolves on the typical timescale for black hole growth, are necessary to understand the observed clustering of mid-IR-selected quasars.

Dating Individual Quasars with the HeII Proximity Effect

Gabor Worseck | University of Potsdam

Abstract

The duration of a quasar accretion episode, the so-called quasar lifetime, is a key quantity for distinguishing between models for the formation and growth of supermassive black holes (SMBHs), quasar evolution, and the potential feedback effects on their host galaxies. However, most methods to infer this critical timescale are indirect, and often involve many model-dependent assumptions, such that estimates of the quasar lifetime are uncertain by orders of magnitude (10^4-10^9 yr). HST/COS UV spectra of quasars probing the z$\sim$3 HeII Lyman alpha forest provide a unique opportunity to precisely measure individual quasar ages, i.e. lower limits on individual quasar lifetimes. Due to the $\sim$30 Myr equilibration timescale of HeII in the z$\sim$3 IGM, the size of the HeII quasar proximity zone depends on the quasar age, enabling precise (up to $+$/-0.2 dex) measurements of individual quasar ages that are comparable to the $\sim$44 Myr e-folding timescale of SMBH growth. By virtue of the long equilibration timescale, HeII proximity zones of z$\sim$3 quasars are two orders of magnitude more sensitive to the quasar age than their HI counterparts at z$\sim$6. We have recently compiled the first statistical sample of 13 quasars whose precise redshifts allow for accurate and precise measurements of HeII proximity zone sizes. Comparing these sizes to predictions from our radiative transfer simulations, we infer a broad range of quasar ages from < 1 to > 30 Myr that does not depend on quasar luminosity, black hole mass, or Eddington ratio. These results point to episodic quasar activity over a long duty cycle, but do not rule out substantial SMBH growth during phases of radiative inefficiency or obscuration. Currently, we are more than doubling our sample with new HST and Gemini data to constrain the distribution of intrinsic quasar lifetimes.

Web of the giant: First spectroscopic confirmation of a large-scale structure around a $z > 6$ super-massive Black Hole

Marco Mignoli | INAF - Osservatorio di Astrofisica e Scienza dello Spazio di Bologna (OAS)

Abstract

We present the spectroscopic confirmation of a large-scale structure around the luminous $z = 6.31$ quasi-stellar object (QSO) SDSS J1030+0524, powered by a one billion solar mass black hole. The structure is populated by at least six members, namely, four Lyman-break galaxies (LBGs), and two Lyman alpha emitters (LAEs). The structure is significant at a level $> 3.5\sigma$ and the level of the galaxy overdensity is at least 1.5-2 within the large volume sampled ($\sim$780 physical Mpc^3). This is the first spectroscopic identification of a galaxy overdensity around a supermassive black hole in the first billion years of the Universe. Our finding lends support to the idea that the most distant and massive black holes form and grow within massive ($> 10^12$ Msun) dark matter halos in large-scale structures and that the absence of earlier detections of such systems is likely due to observational limitations.

Supermassive Black Hole Growth in the Reionization Era: Evolution of Quasar Properties and Demographics

Jan-Torge Schindler | Leiden Observatory

Abstract

The existence of billion solar mass supermassive black holes (SMBHs) within 1Gyr after the Big Bang as inferred from high redshift UV luminous quasars presents a challenge to standard theories of SMBH formation. Dedicated efforts over the last two decades have expanded the redshift frontier to z=7.6 and discovered now more than 400 quasars beyond z=5.7, providing the statistically significant samples necessary to gain first insights into their early assembly. In this talk I will discuss the latest results on the evolution of quasar demographics and quasar properties at high redshift. The Pan-STARRS 1 (PS1) distant quasar survey has discovered more than a quarter of all known quasars above z=5.7. Based on $\sim$120 luminous quasars from the successful PS1 quasar selection and complemented by 42 fainter SHELLQs quasars, I will present a new precise measurement of the z$\sim$6 quasar luminosity function. Going beyond quasar number counts, I will discuss quasar evolution in the context of accretion properties, signatures of gas outflows and feedback, and chemical enrichment of z=5.7-7.5 quasars based on a large sample of 38 reionization-era quasars with multi-wavelength follow-up. However, UV luminous type-I quasars only provide half of the story of SMBH assembly, especially at high redshifts where obscured SMBH growth might play a significant role. Therefore, uncovering the obscured population is critical to complete the picture of SMBH formation and evolution. I will conclude my presentation with an outlook on discovering the obscured quasar population at high redshifts in the near future.

AGN imprints on the IR emission of the first galaxies

Fabio Di Mascia | Scuola Normale Superiore

Abstract

Supermassive black holes (SMBHs, 10^8-$10^{10} M_{sun}$) detected at z$\sim$6 challenge current theoretical models of BH formation and growth, and little is known about their impact on the evolution of the host galaxies. We study the co-evolution of SMBHs with their host galaxies at z$\sim$6 by using a suite of cosmological hydro-dynamical simulations, employing different AGN feedback prescriptions. We post-process the simulations with radiative transfer calculations through dust and we find that the predicted multi-wavelength (UV to FIR) emission is consistent with recent data of high-z quasars. We find that a large fraction (>50%) of the UV radiation in dusty, faint (MUV$\sim$-24) AGN is obscured and re-emitted at rest-frame MIR wavelengths, boosting the MIR-to-FIR flux ratio by a factor $\sim$10-100 with respect to normal star forming galaxies. Our results suggest the possibility to exploit the synergy between JWST and ALMA to unveil faint and/or dust-obscured AGN by measuring their MIR-to-FIR ratio.

Are the First Black Holes More Easily Discovered in the Submillimeter than the NIR?

Amy Barger | University of Wisconsin-Madison

Abstract

I will discuss searching for the highest redshift AGN using ALMA observations on the Chandra Deep Field-South. Some 90 faint submillimeter sources are now known in the central 100 square arcminutes of the field, which is also covered by SCUBA-2 observations. The observed region matches the deepest portion of the 7 Ms Chandra image. With the high spatial accuracy of the ALMA observations, we can measure the X-ray fluxes of the ALMA sources to probe low-luminosity AGN at very high redshifts. Follow-up with ALMA is currently providing spectroscopic redshifts. The region is also covered by the CANDELS and HUDF data, and the optical/NIR and FIR spectral energy distributions provide the best possible photometric redshifts for those sources without spectroscopic redshifts. Almost none of the NIR-selected galaxies at high redshifts are seen in X-rays, and they are also not detected at very low fluxes in the mean. By contrast, the submillimeter-selected sources have a high fraction of X-ray detections at high redshifts and a strong detection in the mean. This could suggest that highly reddened sources dominate the AGN population at the highest redshifts and hence the growth of supermassive black holes at this time.

The Early Universe in a PBH-ΛCDM Cosmology: How a simple solution might solve several difficult problems

Nico Cappelluti | University of Miami

Abstract

We explore the observational implications of a model in which primordial black holes (PBHs) with a broad birth mass function ranging in mass from a fraction of a solar mass to $\sim 10^6$ solar masses, consistent with current observational limits, constitute the dark matter component in the Universe. The formation and evolution of dark matter and baryonic matter in this PBH- LambdaCDM Universe are presented. In this picture, PBH DM mini-halos collapse earlier than in standard LambdaCDM, baryons cool to form stars at z$\sim$ 15-20, and growing PBHs at these early epochs start to accrete through Bondi capture. The volume emissivity of these sources peaks at z$\sim$20 and rapidly fades at lower redshifts. As a consequence, PBH DM could also provide a channel to make early black hole seeds and naturally account for the origin of an underlying dark matter halo - host galaxy and central black hole connection that manifests as the Mbh-sigma correlation. To estimate the luminosity function and contribution to integrated emission power spectrum from these high-redshift PBH DM halos, we develop a Halo Occupation Distribution (HOD) model. In addition to tracing the star formation and reionizaton history, it permits us to evaluate the Cosmic Infrared and X-ray Backgrounds (CIB and CXB). We find that accretion onto PBHs/AGN successfully accounts for the detected backgrounds and their cross-correlation, with the inclusion of an additional IR stellar emission component. Detection of the deep IR source count distribution by the JWST could reveal the existence of this population of high-redshift star-forming and accreting PBH DM.

B1 Probing the relative roles of evolution, orientation and multi-scale gas distributions in shaping the obscuration of black holes through cosmic time

Alba Vega Alonso Tetilla | University of Southampton

Abstract

The nature of obscuration in Active Galactic Nuclei (AGN) is still an open debate. In particular, it is unclear what are the relative contributions to the line-of-sight Hydrogen column densities from galaxy-scale obscuration and from torus-like obscuration from the inner regions. The latter source of obscuration is expected to play a significant role in AGN Unification Models, while the former is relevant in, e.g., AGN Evolutionary Models. In this work we make use of both state-of-the-art semi-empirical models and semi-analytical (GAEA) models to comprehensively probe AGN obscuration properties. To each AGN in our mocks we assign a light curve which is either self-consistently computed via GAEA's latest recipes for supermassive black hole accretion and feedback, or via toy model light curves inspired by hydrodynamic numerical simulations, both fine-tuned to reproduce the observed bolometric AGN luminosity function at different epochs. We first consider basic Evolutionary models assuming different definitions suggested by popular scenarios of what constitutes an optically visible AGN. We assume that an AGN is optically visible only around the peak of the light curve, i.e. when it is sufficiently powerful/luminous to remove the dust around it. We find that this type of model is able to reproduce the fraction of obscured sources with $22<\log NH<24$. However, irrespective of the detailed shape of the light curve or of the "visibility window" of the AGN, we find the same models cannot match the fraction of Compton-thick sources with $\log NH\geq 24$ cm^{-2}. We then move to a more detailed object-by-object modelling of AGN obscuration, in which for each AGN in our mocks we assign a gas fraction with a certain profile, as predicted by GAEA or as guided by direct observations of gas fractions at different redshifts and stellar masses. Irrespective of our input assumptions, we again find that solely galaxy-scale obscuration can hardly reproduce the fraction of Compton-thick sources with $\log NH\geq 24$, which can however still be reproduced by assuming an additional small-scale, torus-like component. The latter must also have an opening angle decreasing with increasing AGN luminosity to match the data on obscured AGN fractions. The fraction of obscured AGN with $22<\log NH<24$ can instead be reproduced by models characterized by a Sersic Hydrogen column density profile. Our results suggest that: a) an evolutionary phase may indeed be present in all AGN, with the optical phase occurring around the peak of the light curve; b) more detailed modelling also suggests that galaxy-scale obscuration may be responsible for most of the obscuration in AGN with $22<\log NH<24$; c) in all cases, even in pure evolutionary models, a long-standing nuclear dusty component is an essential ingredient for the complete description of AGN obscuration.

B2 A panchromatic view of IR quasars: excess star-formation and radio emission in the most heavily-obscured systems

Carolina Andonie | Durham University

Abstract

To fully understand the Active Galactic Nuclei (AGN) phenomenon and their host galaxies, a complete census of AGN activity is required. Recently, some studies in our group have found fundamental differences between blue and red quasars, results that are incompatible with the standard AGN orientation model. To expand these previous studies to more obscured systems, we use the deep and extensive multi-wavelength data in the COSMOS field to select a complete sample of 544 infrared (IR) quasars ($L_{\rm AGN,IR} > 10^{45}\,{\rm erg\,s^{-1}}$) at $z < 3$. We selected our sample by performing a detailed optical/UV-to-FIR spectral energy distribution template fitting utilizing the fully Bayesian code FortesFit. We investigate the X-ray, IR, and radio properties of this large and (near) complete quasar sample and search for differences between the obscured and unobscured systems. We find that, on average, unobscured and obscured IR quasars have fundamentally different properties that cannot be explained by the standard orientation model: obscured quasars have both higher star-formation rates and excess radio emission when compared to unobscured quasars. The excess radio emission in the obscured quasars is due to AGN processes for 80% of the sample, but it is also observed in sources where star-formation processes dominate the radio emission. I will discuss the implications of these results in the context of the SMBH galaxy co-evolution scenario and the AGN orientation model.

B3 Constraints on the X-ray Luminosity Function of AGN at high redshift.

Cassandra Barlow-Hall | The University of Edinburgh

Abstract

Understanding what drives the rapid growth of the first supermassive black holes requires constraints on their number density and growth rates at early cosmic times, which can be traced by the X-ray Luminosity Function (XLF) of AGN. However, due to limitations in survey depth and sky area possible with current telescopes, there has been insufficient data to fit XLF models at $z > 6$, until now. In this talk I will present some of the first constraints on the $z > 6$ XLF. Firstly, I will present work using the new Extragalactic Serendipitous Swift Survey (ExSeSS) catalogue of X-ray selected AGN, which covers $\sim$2000 square degrees. Within ExSeSS we identify one spectroscopically confirmed, serendipitously detected $z > 6$ X-ray AGN, with an Optical-to-X-ray slope consistent with the expected relation. Even with just this one source detected in ExSeSS, and an upper limit on the number of more luminous sources, we are able to place constraints on the bright-end of the XLF at $z = 5.7$-6.4. Next, I will use the combination of high-z galaxy samples combined with deep Chandra data to constrain the AGN occupation fraction and thus place limits on the faint-end of the $z > 6$ XLF. Based on our measurements, we expect ongoing all-sky surveys with eROSITA to detect $\sim$10-100 luminous AGN at $z > 6$, whilst future telescopes such as Athena will be required to fully characterise the faint AGN population at high redshifts.

B4 The impact of growing a giant black hole in the early universe

Jake Bennett | IoA Cambridge -> CfA, Harvard

Abstract

The current and future use of instruments like ALMA, JWST and Athena will allow for a detailed investigation of the surroundings of high redshift massive galaxies, allowing us to probe the processes driving their evolution into galaxy clusters at lower redshift. A particular area of interest is the role that supermassive black holes (SMBHs) play in heating the gaseous haloes around quasars, cutting off inflow and interrupting star formation. SMBHs with a mass in excess of 10^10 solar masses have been discovered at $z > 6$ (e.g. Wu et al. 2015), raising questions about not only how they reach such a size, but also the impact of these monster BHs on their surroundings at early times. Using a zoom-in simulation of the largest halo in the Millennium box, resimulated with a modified version of the FABLE model, we show how we can grow a SMBH to more than 10^10 solar masses before $z = 6$. This extreme object has a number of impacts on its surroundings, heating the CGM and disrupting inflowing filaments, particularly at even higher redshift, leading to a reduction in stellar mass compared to a run without AGN. The size and the shape of the hot halo changes, as it is affected by the interplay between both AGN and stellar feedback, which can also lead to differences in the metal content of the quasar surroundings. The change in the thermal state of the CGM also leads to implications for X-ray and Sunyaev-Zeldovich observations which we explore, with an aim to compare to the latest observations from ALMA and make predictions for Athena.

B5 The properties of outflows and black-hole fueling in FeLoBAL Quasars

Hyunseop Choi | University of Oklahoma

Abstract

Broad absorption-line (BAL) quasars reveal unambiguous evidence for powerful Active Galactic Nuclei (AGN) outflows in their rest-UV spectra. The BAL winds are thought to be one of the critical drivers of quasar feedback that influences the evolution of their host galaxies as well as the accretion processes of the central supermassive black holes (SMBHs). BAL quasars typically have redder optical colors, suggesting that they may represent a short-lived "blowout" phase in quasar evolution where the quasar blows out its cocoon of gas and dust. Therefore BAL quasars are excellent targets for studying the evolution of quasars and the interactions between the black-hole fueling and AGN winds. Using the state-of-the-art spectral analysis software, we performed the first systematic study of a large sample of iron low-ionization BAL (FeLoBAL; a subtype that has iron absorption lines) quasars. We analyzed the spectra of 50 low-redshift ($0.66 < z < 1.63$) FeLoBAL quasars observed by SDSS/BOSS and constrained the physical properties of the BAL outflows, increasing by a factor of five the number of objects with detailed analysis. We found a large range of ionization parameters and densities in the outflow gas as well as a wide range of distances from the central supermassive black holes, ranging from torus scales (∼pc) to host galaxy scales (∼kpc). From our sample, faster and more energetic outflows were found in redder or more luminous objects. We analyzed the accretion properties of the central SMBHs for a subset of 30 objects that had rest-optical spectra and discovered compelling evidence that the properties of Eddington-normalized accretion rate of FeLoBAL quasars were different than unobscured comparison sample. Our work demonstrates exciting observational evidence for the physical connection between AGN outflows and black-hole fueling.

B6 Observing and modelling the gas and dust of the most luminous galaxy known

Román Fernández Aranda | ESO

Abstract

W2246-0526 is a Hot Dust Obscured Galaxy at redshift 4.6, and the most luminous galaxy known to date. It harbors a heavily obscured super-massive black hole that is accreting at or above the Eddington limit. Observations with ALMA of the the brightest far-IR fine-structure emission lines as well as of their underlying dust continuum, in combination with a large grid of CLOUDY radiative transfer models, are used to constrain the interstellar medium of the central quasar and its host galaxy. We find that intense X-ray emission is required to reproduce observed emission line ratios.

B7 Spectral Synthesis Analysis of Broad Absorption Line Quasars

Karen Leighly | University of Oklahoma

Abstract

Broad absorption line quasars present unassailable evidence of outflows in their rest-UV spectra. However, the properties of these outflows, including where they are located in the quasar, how much energy they carry, or whether there is a relationship between outflows and black-hole fueling, are still generally unknown. I will introduce our forward-modeling spectral synthesis method for modeling broad absorption line quasar spectra. Iron Low-Ionization Broad Absorption Line quasars (FeLoBALQs) are a class of BALQ that is characterized by absorption from thousands of Fe II lines in the near-UV. Although rare, it is possible that some FeLoBALQs represent a stage in the evolution of a quasar. Building on our completed detailed analysis of a sample of low-redshift FeLoBALQs that revealed a wide range of outflow locations and two classes of FeLoBALQs differentiated by their accretion rate, I will present the first results of an infrared spectroscopic program designed to investigate how the outflow properties of FeLoBALQs depend on both the quasar luminosity and accretion rate. I will also present our convolutional neural net classifier that is trained using synthetic spectra generated by our spectral synthesis method. This classifier can be used to determine the population statistics of BAL quasars in current and upcoming surveys such as 4MOST. Detailed analysis of samples of BAL quasars linking the outflow properties to the accretion rate and determining the fractional content of BAL quasars enhance our understanding of the relationships between outflows and black-hole fueling.

B8 Detecting short-lived AGN flares

Summer McLaughlin | University of Sheffield

Abstract

Extreme variability of AGN, showing large luminosity changes that are statistically significant from the baseline variability, are known as AGN flares. AGN flares are defined in a quantitative manner as exhibiting luminosity changes above the typical stochastic variability of AGN. Current models suggest that their origin is due to changes in accretion state caused by magnetic reconnection in the disc, but there are a number of other explanations for this including microlensing, binary black hole mergers, tidal disruption events and superluminous supernovae. Less than 100 of these events have been detected, over timescales of hundreds to thousands of days. There has been little investigation into whether these events can happen on timescales shorter than this, and we propose that a different detection technique than previously used is required to identify these events from stochastic AGN variability. The next decade of research in this field will be pivotal to the current categorisation of AGN flares, and it is hoped that future high-cadence surveys will enable the detection and monitoring of these events in real-time. In the era of the Vera Rubin Observatory, many more of these events will be identified so that they can be better categorised and the dynamics of the central black hole and accretion disk can be further constrained.

B9 CON-quest: dense molecular gas properties in moderately luminous infrared galaxies

Kyoko Onishi | Chalmers University of Technology

Abstract

We present ALMA observations of dense molecular gas at 50pc resolution in galaxies moderately luminous in infrared (10^{10-11} Lsun; subLIRGs). Recent observations towards luminous infrared galaxies (LIRGs) discovered a population of galaxy nuclei that seem to be undergoing intensive growth. Such a nucleus is called a compact obscured nucleus (CONs), and one of the key points of CONs is the extreme environment indicated by it's compactness ($<$100pc) and large column density ($N_{H\square}>10^{25}/cm^2$). A survey for CONs (Falstad et al. 2021; CON-quest) showed that CONs exists primarily in (U)LIRGs, and galaxies with moderate infrared luminosity (subLIRGs) do not seem to have CONs. By using a complete sample of subLIRGs until 15Mpc distance, we discuss possibilities of future manifestation of CONs in such galaxies.

B10 Public release of Near-infrared and Optical Spectroscopy of Reionization-era Quasars at z>6.5

Silvia Onorato | Leiden University

Abstract

We present the results of near-infrared and optical spectroscopic observations for a sample of quasars at z > 6.5 which will be made publicly available. The spectra are taken with Keck/NIRES, Gemini/GNIRS, and VLT/X-Shooter spectrographs and reduced with the open-source Python-based spectroscopic data reduction pipeline PypeIt. These spectra will be useful for several scientific goals, i.e. studying the Ly-alpha Forest, IGM metal content and temperature, quasar properties themselves (e.g. super massive black hole masses and growth, Eddington ratios, Quasar Luminosity Function), and also damping wings and proximity zones. The strengths of this data sample consist in different factors, such as the big amount of public quasar released, their homogeneity and reproducibility, but also the high spectral resolution. All of these properties allow for improved modeling of both damping wings and proximity zones. This represents an essential step for reconstructing quasar spectra continuum predicting the intrinsic blue-side from the observed red-side (PCA continuum model), and thus inferring information both on the average hydrogen neutral fraction at the epoch of Reionization and on the growth of the first super massive black holes.

B11 How do SMBHs populate halos at the high redshift? Interpreting the observed clustering and abundance of quasars with large-volume cosmological simulations

Elia Pizzati | Leiden Observatory

Abstract

Luminous quasars are the most highly clustered objects known at $z \approx 4$. This fact has profound consequences for our understanding of supermassive black holes (SMBHs) and their evolution over cosmic time. Such a large clustering implies that quasars are a rare phenomenon, arising only in the most massive halos and shining for a large fraction of the Hubble time. Previous work on quasar demographics highlighted that these conclusions contrast with the situation at lower redshifts, where quasars represent a relatively common, brief phase in galaxy evolution. Studying this problem theoretically is particularly challenging, as one has to obtain a reliable statistical sample of the most biased and extreme dark matter environments at high redshift. In this project, we overcome this obstacle by populating the new, extremely large-volume ($L \approx 5$ cGpc) FLAMINGO cosmological simulation with quasars, using a demographic model that makes only a few assumptions on the phenomenology of galaxy formation. In this way, we are able to investigate the predictive power of quasar observables in a pure LCDM framework. By simultaneously matching the correlation function of luminous quasars and the bolometric quasar luminosity function, we obtain physical constraints on the Eddington ratio distribution function, the halo mass distribution of quasar hosts, and the quasar duty cycle. Finally, we discuss the implications of these results in light of the current paradigm of SMBHs growth and their interplay with the surrounding environment.

B12 Sub-grid modelling of supermassive black hole accretion, spin evolution and feedback in hydrodynamical simulations

Luca Sala | Universitäts-Sternwarte München - Fakultät für Physik der Ludwig-Maximilians-Universität

Abstract

Active galactic nuclei (AGNs) are massive black holes (BHs) caught in the act of accreting gas at the centre of their host galaxies. In this process, a great amount of energy is released into the surrounding medium, in a process loosely referred to as AGN feedback. Numerical simulations are a powerful tool to study the complex non-linear interaction between massive BHs and their surrounding environment and host galaxies, but usually we are not able to resolve all the relevant scales involved, due to limited computational resources, therefore we have to rely upon sub-grid, effective models. I will present my work, which focuses on the design and implementation of such models for accretion and feedback, to be applied in cosmological hydrodynamical simulations. Regarding the treatment of accretion, my work aims at adding an intermediate step in the mass transfer from the resolved scales of the simulation onto the BH, through the inclusion of a sub-grid accretion disc. The model self-consistently evolves the disc properties as well as the BH spin due to gas accretion and I will present the results of simulations that test such a model in idealised setups. The BH spin evolution model will be then coupled to a prescription for energy injection aimed at reproducing the interaction of jets from AGNs with the surrounding medium, as we observe in features like radio lobes.

B13 An insight of SMBH-host galaxy coevolution through dual quasar systems in Subaru HSC-SSP

Shenli Tang | University of Tokyo

Abstract

I will report on a spectroscopic program to search for dual quasars using Subaru Hyper Suprime-Cam (HSC) images of SDSS quasars, which represent an important stage during galaxy mergers. Using the full sample of six spectroscopically confirmed dual quasars, we find that the black holes in these systems have black hole masses similar to single SDSS quasars as well as their bolometric luminosities and Eddington ratios. We measure the stellar mass of their host galaxies based on 2D image decomposition of the five-band (grizy) optical emission and assess the mass relation between supermassive black holes (SMBHs) and their hosts. Dual SMBHs appear to have elevated masses relative to their host galaxies. Thus mergers may not necessarily align such systems onto the local mass relation, as also suggested by the Horizon-AGN simulation. We suggest that dual luminous quasars are triggered prior to the final coalescence of the two SMBHs, resulting in early mass growth of the black holes relative to their host galaxies.

B14 Growth of galaxies and supermassive black holes in the cosmic web filaments at $z = 3$

Hideki Umehata | Nagoya University

Abstract

A generic prediction in a cold dark matter universe is the presence of a network of filaments, at the intersection of which galaxies form and evolve. Therefore, supermassive black holes (SMBHs) and host galaxies that reside in the remarkable intergalactic medium (IGM) filaments are at a crucial stage wherein they rapidly grow while acquiring fuels. In this regard, the core region of the $z = 3.1$ SSA22 protocluster provides an important laboratory. Within the 2×3 arcmin^2 region at the core, 16 ALMA-identified submillimeter-galaxies (SMGs; SFR 200 - 2000 Msun/yr) and 8 X-ray AGNs ($L_X \sim 10^{44}$ erg/s) (6 galaxies overlapped, and all 18 galaxies had spec-$z = 3.09$) were found, which shows that the volume density of SMGs and X-ray AGNs at the proto-cluster core is 2-3 orders greater than the field. Furthermore, all these active galaxies were ubiquitously embedded in the Mpc-scale Lyman-alpha filaments in 3D. This suggests that the growth of galaxies and black holes are simultaneously accelerated at the core of the protocluster fed by the gas filaments of the cosmic web.

B15 The MUSE view of the CON NGC4418

Clare Wethers | Instituto de Astrofísica de Canarias

Abstract

(Ultra-) luminous infrared galaxies (U)LIRGs host the most extreme starbursts in the local Universe and have been shown to commonly exhibit outflows. Such outflows distribute material and inject energy into the ISM, regulating both star formation in the galaxy and accretion onto the central supermassive black hole. In recent years, a significant fraction (20-40 per cent) of local (U)LIRGs have been shown to host compact (r<100 pc) obscured nuclei (CONs) with extreme nuclear column densities, NH2 » 1024 cm2. While the nature of these CONs remains unclear, with both an AGN and/or starburst activity suggested as potential nuclear power sources, it is possible that CONs play a critical role in galaxy evolution, marking an early obscured phase of AGN activity. Due to their increased star formation and high gas column densities, CONs provide ideal laboratories in which to study star formation and quenching in extreme ISM conditions. I will present new, targeted integral field unit (IFU) observations from the Multi-unit Spectroscopic Explorer (MUSE) for the local CON NGC4418. Based on kinematic measurements, we reveal the presence of a decelerating, centrally concentrated optical outflow and slow-rotating ionized gas. For the first time, we also uncover the presence of bright OIII 5007 knots throughout the galaxy, potentially ionised by recent or ongoing AGN activity in NGC4418.

R-B1 Revealing the Growing Nuclear Structure of IC 860s Compact Obscure Nucleus

Mark Gorski | Chalmers University of Technology

Abstract

Compact Obscured Nuclei (CONs) are galactic nuclei, with radii of 10-100 pc, are optically thick at frequencies above 80GHz, and characterized by vibrationally excited HCN emission. CONs account for 30% of the population of luminous and ultraluminous infrared galaxies (LIRGs and ULIRGs). Hiding either a rapidly accreting supermassive black hole or an abnormal mode of star formation, they represent an extreme phase of nuclear growth. Principal component analysis (PCA) tomography of high-resolution ALMA observations reveal morphological features in molecular emission that suggest a rotating, in-falling disk or envelope, and an outflow. Our analysis suggests that this important stage of nuclear evolution in galaxies is morphologically similar to scaled up Milky Way hot cores, e.g., super hot cores.

R-B2 Probing the Inner Circumgalactic Medium and Quasar Illumination around the Reddest 'Extremely Red Quasar' (ERQ)

Marie Wingyee Lau | University of California, Riverside

Abstract

Dusty quasars might be in a young stage of galaxy evolution with prominent quasar feedback. I study a population of luminous, extremely red quasars at z$\sim$2-4 that has extreme spectral properties that may be related to exceptionally powerful quasar-driven outflows. I will present Keck/KCWI observations of the reddest known ERQ, at $z = 2.3184$, with extremely fast [OIII]5007 outflow at $\sim$6000 km s^{-1}. The Lyα halo spans $\sim$100 kpc. The halo is kinematically quiet, with velocity dispersion $\sim$300 km s^{-1} and no broadening above the dark matter circular velocity down to the spatial resolution $\sim$6 kpc from the quasar. Spatially-resolved HeII1640 and CIV1549 emissions are detected with kinematics similar to the Lyα halo and a narrow component in the [OIII]5007. Quasar reddening acts as a coronagraph allowing views of the innermost halo. A narrow Lyα spike in the quasar spectrum is inner halo emission, confirming the broad CIV1549 in the unresolved quasar is blueshifted by 2242 km s^{-1} relative to the halo frame. The inner halo is dominated by past/moderate-speed outflow and the outer halo dominated by inflow. The high central concentration of the surface brightness and the circularly symmetric morphology of the inner halo are consistent with the ERQ being in earlier evolutionary stage than blue quasars. The HeII1640/Lyα ratio of the inner halo and the asymmetry level of the overall halo are dissimilar to Type II quasars, suggesting unique physical conditions for this ERQ that are beyond orientation differences from other quasar populations. No evidence of mechanical quasar feedback is found on circumgalactic scales. Finally, I will present preliminary Keck/OSIRIS observations of this reddest ERQ.

R-B3 Criticism of the identification of metric-tensor component with mass and a model of stupendously large primordial galactic object

Lubos Neslusan | Astronomical Institute, Slovak Academy of Sciences, Tatranska Lomnica, Slovakia

Abstract

When a realistic model of relativistic compact object (RCO) is created, it is demanded that only the normalized solution of the field equations can be used. We point out that this demand crucially depends on the identification of g_{rr} component of metric tensor (spherical symmetry is assumed) with the mass, which is however a scalar quantity. This identification is a mistake and must never be done. If done, an essential part of the general relativity is prohibited to be used in the RCO modeling. Presenting an example, we show the possible consequences of the abolition of normalization demand. Specifically, the compact object in the galactic center and galactic dark-matter halo can be modeled as a single whole, single RCO, and there is no event horizon. This RCO is in a stable-equilibrium configuration, with positive pressure and energy density in its interior (zero in neighboring vacuum), and a continuous metrics smoothly tailored with the vacuum metrics. Via a reverberation mapping or using other method, we measure, in fact, the special form of g_{rr} component (let us name it as the "metric mass-equivalent") characterizing the gravity in neighborhood of the central compact object, but the mass (energy content) of the object can be several orders of magnitude larger. For example, the metric mass-equivalent can equal $10^9\,\mathrm{M}_\odot$, but the mass can be, say, $10^{14}\,\mathrm{M}_\odot$. The RCOs, which later became the galaxies, could form as the stupendously large primordial objects in few hours after the Big Bang. If only a tiny fraction of mass was ejected from the central condensation, there was enough material to form all the structures observed within a whatever galaxy, etc.

R-B4 Field variance forecasts of high redshift AGNs for future surveys with a semi-analytic model

Taira Oogi | Ehime University

Abstract

Measurements of the luminosity function of active galactic nuclei (AGN) at high redshift ($z \gtrsim 4$) are expected to suffer from field-to-field variance, including the cosmic variance and Poisson variance. Future surveys, such as JWST and Euclid, can also be affected by field variance. We use the Uchuu simulation, a state-of-the-art cosmological N-body simulation with volume $25.7 \sim \mathrm{Gpc}^3$ and sufficient mass resolution, combined with a semi-analytic galaxy and AGN formation model, the New Numerical Galaxy Catalog (ν^2GC), to investigate the field-to-field variance of the luminosity function of AGNs. With this Uchuu–ν^2GC model, we quantify the cosmic variance, σ_{cv}, as a function of survey area, AGN luminosity, and redshift. The cosmic variance decreases with increasing survey area and decreasing redshift. We find that σ_{cv} hardly depends on the AGN luminosity. This is because the typical dark matter halo mass in which AGNs reside does not monotonically increase with increasing luminosity. Due to the rarity of AGNs, the Poisson variance dominates the total field-to-field variance, in particular, for bright AGNs. We also examine the effects of parameters related to galaxy formation physics on the field variance. We discuss the uncertainties in the estimations of the faint end of AGN luminosity function in recent observations. Finally, we predict the expected numbers of AGNs and their variance discovered by new observations with JWST, Euclid, and LSST. We predict that 120-240 (16-80) AGNs (depending on the models) with the rest-frame UV absolute magnitude brighter than -20 (-20.5) will be observed at z=6.3 (7) in the Euclid H-band for the Euclid deep survey. For the Euclid wide survey, we also predict that 15000-45000 (3000-15000) AGNs with the UV magnitude brighter than -22 (-22.5) will be detectable at z=6.3 (7).

R-B5 A Study of Heavily Obscured Quasars with Young Radio Jets at z 2

Pallavi Patil | NRAO

Abstract

Active Galactic Nucleus (AGN) feedback at z 1-3 is believed to take place in the presence of thick columns of gas and dust, leading to heavily obscured systems that are challenging to detect at optical and X-ray wavelengths but are transparent at radio and Mid-IR wavelengths. Mid-IR color diagnostics using WISE observations can identify the most luminous and heavily obscured AGNs, which are believed to represent a transient phase of rapid massive black hole growth. By combining both Mid-IR and radio diagnostics, we have identified a sample of 155 ultra-luminous and obscured quasars ($0.4 < z < 3$) selected to have extremely red Mid-IR colors in WISE and compact, bright (>7 mJy) radio emission in the NVSS Survey and FIRST. In this talk, I present results from radio and submillimeter follow-ups of our sample. High-resolution VLA imaging has revealed compact source morphologies on angular scales < 0.2" (1.7 kpc at z 2) for the majority of our sources. Then, I present broadband radio spectra of the entire sample, constructed from our 10 GHz VLA observations and archival radio data. About half of our sample exhibits peaked or curved spectral shapes consistent with those typically seen in young radio AGN (e.g., Gigahertz Peaked Spectrum and Compact Steep Spectrum sources). The application of a simple adiabatic lobe expansion model is consistent with the radio jets that are relatively young ($<$ 0.01-10 Myr) and propagating into a dense ambient medium. The presence of a dense ISM is further supported by the direct detection of large molecular gas reservoirs in a pilot follow-up study with the ALMA. Overall, our sample is consistent with a population of recently triggered, young radio jets caught in a unique evolutionary stage in which they reside in a dense ISM. Finally, I discuss the implications of our study for understanding the impact of young jets on the ISM and star formation rates in powerful young AGN.

R-B6 Origin of supermassive black holes in massive metal-poor protoclusters

Dominik Schleicher | University of Concepción

Abstract

For the origin of the first supermassive black holes in the Universe, different scenarios have been proposed, ranging from the direct collapse of massive gas clouds into one single object, run-away collisions in very dense stellar clusters, as well as accretion of initially stellar-mass black holes. In this talk, I will show how realistic scenarios will have to combine these approaches to allow significant growth both via stellar collisions and gas accretion. The combination of the two processes includes additional means of dissipation, thereby makes collisions more likely and more efficient, and alleviating the fragmentation problem in the context of the gas. I will present results both from numerical simulations that take both the hydrodynamics and the stellar dynamics into account, as well as complementary analytical work to show how the combination of both processes leads to the formation of supermassive black holes.

R-B7 Hyper-Eddington Black Hole Growth in Star-Forming Molecular Clouds and Galactic Nuclei

Yanlong Shi | California Institute of Technology

Abstract

Formation of supermassive black holes (BHs) remains a theoretical challenge. In many models, especially beginning from stellar relic "seeds," this requires sustained super-Eddington accretion. While studies have shown BHs can violate the Eddington limit on accretion disk scales given sufficient "fueling" from larger scales, what remains unclear is whether BHs can capture sufficient gas from their surrounding ISM. We explore the problem in a suite of multi-physics high-resolution simulations of BH growth in magnetized, star-forming dense gas complexes including dynamical stellar feedback from radiation, stellar mass-loss, and supernovae, exploring populations of seeds with masses $\sim 1-10^4\,M_\odot$. The simulations support the key role of stellar feedback in shaping proper environments for significant BH seed accretion, which is also highly correlated with properties of giant molecular clouds. We then further consider multiple BH feedback effects by including sub-grid models of photon momentum, HII/Compton heating, mechanical outflow, and the cosmic ray. As a parameter survey, we find that BH growth is more regulated by the mechanical feedback but still possible in some environments like dense molecular clouds and galactic nuclei.

R-B8 The Obscured Fraction of Quasars at Cosmic Noon

Bovornpratch Vijarnwannaluk | Tohoku University

Abstract

Statistical studies of X-ray selected AGN indicate that the fraction of obscured AGN increases with increasing redshift, and the results suggests that a significant part of the accretion growth occurs behind obscuring material in the early universe. We investigate the obscured fraction of highly accreting X-ray AGN at around the peak epoch of SMBH growth utilizing the wide and deep X-ray and optical/IR imaging datasets. A unique sample of luminous X-ray selected AGNs above $z > 2$ was constructed by matching the XMM-SERVS point-source catalog with a PSF-convolved photometric catalog covering from u^* to 4.5μm band. Photometric redshift, column density, and 2-10 keV AGN luminosity of the X-ray selected AGN candidates were estimated. Using the sample of 305 2-10 keV detected AGN at above redshift 2, we estimate the fraction of AGN with $\log N_{\rm H}\ (\rm cm^{-2}) > 22$, assuming parametric X-ray luminosity and absorption functions. The results suggest that $67 \pm 4\%$ of luminous quasars ($\log L_X\ (\rm erg\ s^{-1}) > 44.5$) above redshift 2 are obscured which indicates an increased contribution of obscured accretion at high redshift than that in the local universe. We discuss the implications of the increasing of the obscured fraction with increasing redshift based on the AGN obscuration scenarios, which describes obscuration properties in the local universe. Both obscured and less-obscured $z > 2$ AGN show a broad range of SEDs and morphologies, which may reflect the broad variety of host galaxy properties and physical processes associated with the obscuration.

R-B9 Tracing the onset of the AGN feeding-feedback cycle in the nearby super-Eddington NLS1 Mrk 1044

Nico Winkel | Max-Planck-Institut fÃ¼r Astronomie

Abstract

The host galaxy conditions required for rapid supermassive black hole growth are poorly understood. Narrow-line Seyfert 1 (NLS1) galaxies often exhibit high accretion rates and are hypothesized to be archetypes of active galactic nuclei (AGN) at early stages of their evolution. As part of the Close AGN Reference Survey (CARS) we have obtained adaptive optics assisted VLT MUSE narrow field mode (NFM) observations of Mrk 1044, the closest (80 Mpc) NLS1 that accretes above the Eddington limit. The unprecedented NFM resolution of 80 mas (17 pc) allows us to trace the host galaxy ISM conditions and resolve the circumnuclear star formation from galaxy scales down to the center. I will discuss how star formation induced ejecta from massive stars could explain the high black hole accretion rate. Although star formation appears to be the dominant ionization mechanism even near Mrk 1044's nucleus, we detect a pc-scale high density outflow in both [O III] emission and Ly-alpha absorption. Using an expanding shell model, I will discuss its origin, geometry and future impact of this outflow on the host galaxy. This method has the potential to trace the onset of the AGN feedback down to scales of the central engine. Our results stress the importance of investigating the AGN-host interaction on different spatial, time and density scales and have far-reaching implications for understanding black hole fuelling and feedback in its complexity.

Oral & Poster Programme Abstracts

Friday, 30th September 2022

Session 4: What impact do AGN winds/jets/outflows have on the black-hole fueling and star formation?

The many roads to AGN feedback

Tiago Costa | Max Planck Institut für Astronomie

Abstract

I will start by revisiting the original arguments laid out for the need of AGN feedback in the light of today's theoretical understanding of galaxy evolution. I will describe advances in our grasp of the various physical mechanisms through which such feedback comes about, including momentum- and energy-driving, jets, winds and radiation pressure and how they might couple the properties of supermassive black holes to those of their host galaxies. I will illustrate how these early ideas have been reshaped by new sophisticated cosmological simulations and the increasingly detailed models of AGN feedback that have emerged over the last decade. Backed by results from these simulations and new observations of AGN outflows, I will (i) make the case for "energy-driven" winds as the main AGN feedback mechanism, (ii) call the division of AGN feedback into radio- and quasar "modes" into question and (iii) illustrate how AGN feedback operates over a range of timescales, with the window for rapid "blow-out" episodes as the chief star formation suppressant narrowing considerably. An updated catalogue of predicted imprints of AGN activity on galaxy and black hole properties will be presented, with emphasis placed on newly-unveiled feedback effects, such as the impact of AGN on galaxy morphology, and the state of the interstellar- and circum-galactic media. Finally, I will reflect on the progress made in the last decade in constraining theory with observations, discussing the pitfalls of this exercise and highlighting the new questions about the role of AGN in galaxy evolution this work has begun to generate.

AGN feedback signatures from small to large scales

Dominika Wylezalek | University of Heidelberg, Astronomisches Rechen-Institut

Abstract

AGN feedback is now widely considered to be one of the main drivers in regulating the growth of massive galaxies. In my talk I will describe several efforts in our group to understand the power, reach and impact of AGN feedback processes. We find significant evidence for AGN feedback signatures even in low-luminosity AGN and we are now the large molecular gas survey MASCOT as a tracer to investigate if and how feedback may impact and quench galaxies at low redshift. At higher redshift, it appears that AGN-driven outflows can indeed suppress star formation in their hosts, consistent with the AGN having a 'negative' impact on galaxy evolution. However, both star formation and quasar activity peak at z $\sim$ 2-3 where AGN are expected to impact the build-up of stellar mass the most and I will present recent efforts in our group to characterise feedback processes in powerful AGN on CGM scales at and near Cosmic Noon. In particular, our team recently discovered a unique population of luminous high-z quasars with extreme outflow properties. At the same time, more and more exotic AGN populations with extreme signatures are being discovered at that redshift. These populations are ideal to obtain a census of the overall mass and energy budget of both outflow and infall/feeding from the CGM, an essential requirement to probe the detailed and full feedback loop. Finally, I will also introduce the JWST ERS Program "Q3D" which will study the impact of three carefully selected luminous quasars on their hosts. Our program will serve as a pathfinder for JWST science investigations in IFU mode. Depending on JWST's science schedule, I may show some of the very first JWST science data.

Dissecting the obscuration and outflow of AGN in Circinus galaxy

Marko Stalevski | Astronomical Observatory of Belgrade

Abstract

Circinus is the closest Seyfert 2 galaxy and harbors the second brightest active galactic nucleus (AGN) in the mid-infrared (MIR), allowing high angular resolution studies across a range of wavelengths. Recent MIR interferometry and single dish imaging, together with detailed radiative transfer modeling, have cast this galaxy in a major role: a prototype in the emerging paradigm of 'polar dust AGN', in which a major fraction of the MIR emission is associatedwith dusty winds blown away from the sublimation zone by the radiation pressure. I will present our recent and ongoing efforts in understanding the obscuration and outflows in this object from parsec scale, to tens and hundreds of parsecs. Namely, we have launched a campaign to acquire highest angular resolution images of the nucleus and ionization cone with several instruments mounted on the VLT: optical polarimetry with FORS2; IFU observations with MUSE in the narrow field mode; MIR imaging with VISIR in the sparse aperture masking and corohography modes. All these observations, along with state-of-the-art radiative transfer modeling, paint a consistent picture: a compact dusty disk responsible for obscuration and feeding of the black hole, and a dusty outflow in the polar direction, illuminated by anisotropic and misaligned accretion disk; the dusty outflow extends into the ionization cone and produces some peculiar features in interaction with the immediate surroundings in the host galaxy.

The Keck OSIRIS Nearby AGN Survey: Tracing Fueling and Feedback in local AGN

Erin Hicks | University of Alaska Anchorage

Abstract

The Keck OSIRIS Nearby AGN (KONA) survey aims to characterize the feeding and feedback processes within the central 500 pc of a sample of 40 local, representative AGN. Using AO-assisted K-band IFU observations the distribution and kinematics of the of the circumnuclear stars (CO 2.29 micron bandheads), molecular gas (H2 2.12 microns), and ionized gas (Br G and [Si VI] emission at 2.16 and 1.96 microns, respectively) are traced down to scales of tens of parsecs. With few exceptions, the observed stellar velocity field is well reproduced by a rotating disk, and the kinematic position angle is found to be consistent with the near-IR photometric axis of the host galaxy. The molecular gas emission is found to follow a similar radial distribution as the stars, while the ionized gas is more centrally concentrated and has a relatively high velocity dispersion (typically twice that of molecular hydrogen) indicative of outflows. The molecular gas is found to be primarily rotating in the plane of the galaxy with relatively low velocity dispersion, although evidence of inflow and/or outflow is also identified in most cases. Furthermore, in half of the sample a misalignment of the molecular gas and stellar disk is found. The level of deviation from disk rotation associated with radial motions in the molecular hydrogen correlates with hard X-ray luminosities, suggesting that within the circumnuclear region AGN feedback is more significant in more luminous AGN. The total ionized gas mass within $r < 100$ pc ranges from (7-30) x 10^5 Msun, with surface mass densities of 1-100 Msun/pc^2. Within this same region the total molecular gas is found to be $10^3 - 10^5$ times lower, with surface mass densities of 0.7-12 x 10^{-2} Msun/pc^2. This suggests an available gas reservoir within the central 200 pc exceeds that needed to feed the AGN by at least one, and up to three, orders of magnitude is typical in local AGN.

Let's talk about Jets: Analyzing Extranuclear Radio Sources in NGC 1068

Travis Fischer | Space Telescope Science Institute

Abstract

We present multi-epoch VLBA interferometry and multi-wavelength HST imaging to study the characteristics of the extranuclear radio emission in prototypical Seyfert 2 NGC 1068. From our recent studies, we have noted that radio structures in previous analyses of radio-quiet AGN align and intertwine with their optical Narrow-Line Regions (NLRs), which represent the intersection between AGN ionization and host galaxy disk material. We hypothesize that radiatively-driven winds, launched from small radii, impact dense gas lanes at larger distances and produce shocks, with relativistic particles accelerated in the shocks in turn producing localized synchrotron radio emission similar to processes in supernova remnants. In this scenario, the observed radio emission is then a byproduct that occurs only at locations where winds are producing shocks in the radio-quiet AGN host galaxy. As this hypothesis lies in tension with the standard paradigm of radio structures in AGN, we present further testing on the radio structures observed in NGC 1068 to provide evidence for this scenario on how AGN produce feedback and interact with the interstellar medium in their host galaxies.

Elucidating the impact of galaxy substructure on black hole growth and AGN feedback

Stephanie Juneau | NOIRLab

Abstract

Despite the tremendous progress made to improve our knowledge of the black hole-galaxy connection, we still have major gaps in our understanding of the role of AGN feedback in driving galaxy evolution and in self-regulating black hole growth. We now routinely find observational signatures of AGN-driven outflows, and we know that this material can entrain and/or heat gas along the way but mysteries remain regarding their actual impact on the host galaxy. I will present a detailed case study of nearby active galaxy NGC 7582 for which we found an important role played by galaxy substructure (namely a $\sim$600 parsec ring structure) in collimating the AGN outflows, possibly shielding the main galaxy disk from AGN feedback. This analysis was possible thanks to exquisite quality 3D spectroscopy from Very Large Telescope (VLT)/MUSE with $>$90,000 spaxels spanning a square arcmin field-of-view (8 kpc across for NGC 7582). We mapped the stellar and gas kinematics as well as ionized gas properties, clearly distinguishing between the rotating galactic disk and the AGN-photoionized outflow. We augment the analysis using ALMA observations that had revealed a molecular torus and a ring likely responsible for black hole growth. Intriguingly, this system likely experiences AGN feedback from both a radio jet and an accretion disk wind simultaneously. While such detailed observations and analyses are currently only feasible for nearby (or lensed) galaxies, they give us a preview of technical feats that we could achieve at higher redshifts with JWST or with the large aperture telescopes (ELTs)

Testing the Limits of AGN Feedback in the Most Rapidly Star Forming Brightest Cluster Galaxies

Michael Calzadilla | MIT

Abstract

For years we have grappled with the "cooling flow problem" in galaxy clusters, where the massive reserves of hot (10^7 K) gas in the intracluster medium (ICM) have been universally observed to form stars with an efficiency of only 1-10%. Feedback from accreting active galactic nuclei (AGN) has been identified as the likely heating source capable of suppressing runaway cooling by up to two orders of magnitude. However, with the recent discovery of the Phoenix cluster exhibiting the only known pure cooling flow, the thermostat of AGN feedback appears to be broken in this and a few other highly accreting systems. In this study, we use new, deep Hubble observations to map out massive, intricate [OII] emission line nebulae in exquisite detail in a handful of the most rapidly star forming central cluster galaxies in the Universe. From these maps of cool (10^4 K) gas we can measure accurate star formation rates (SFRs), which we use together with systems from the literature spanning several orders of magnitude in ICM cooling rates (dM/dt, as measured from Chandra X-ray data) to determine the efficiency with which the ICM cools. We find a steeper than unity relationship between SFR and dM/dt, indicating perhaps a gradual saturation point for AGN feedback in the strongest cooling systems (i.e. dM/dt >1000 Msun/yr), where feedback from the central supermassive black hole is being overwhelmed by the prodigious deposition of cooling material. We also use the maximum extent of cool gas as measured from our [OII] maps along with Halpha measurements from the literature and compare these to features in the ICM to weigh in on the hotly-debated issue of identifying what criteria best predict the onset of thermal instability in the ICM.

How can we determine the source of the enhanced radio detection fraction of quasars with strong winds?

James Petley | Durham University

Abstract

Broad absorption line quasars (BALQSOs) show strong signals of fast-moving, outflowing gas in their spectra. These outflows make BALQSOs natural feedback candidates as it has been shown the a significant fraction of the energy of the quasar can be transferred into these winds. The fact that these winds likely do not last longer than ∼100Myrs but at least 20% of quasars contain them across redshift suggests that BALQSO winds could be one of the primary methods in which black holes interact with their galaxies. Quasars that show these signals have a puzzling enhancement in their radio detection fraction, showing around 2-3 times the detection fraction of the general population. Despite knowledge of this high detection rate for over a decade, the physical origin of this radio enhancement is unknown. Radio surveys to date have not been deep enough to rule out different emission mechanisms in these largely radio-quiet sources. I will present results from my recently submitted paper, using the latest LOFAR Two-Metre Sky Survey DR2 results. We create composite spectra to connect the radio detection of BALQSOs with various wind properties such as wind strength and observed reddening of the sources. We consider different radio emission mechanisms within BALQSOs, including star formation and radio jets, and favour a wind shock emission explanation. I will discuss interpretations of my work so far and present how a VLBI follow-up project intends to resolve some of the current unknowns surrounding BALQSOs and radio-quiet quasars more generally.

MASCOT: Gas-phase metallicity gradients as a probe of outflows, star formation and inflows as active galaxies transition to the red cloud

Caroline Bertemes | Heidelberg University

Abstract

The gas-phase metallicity gradients within galaxies are imminently responsive to in-situ star formation, inflows, and outflows. As such, they constitute a powerful probe of feedback mechanisms in principle, provided one can disentangle the different drivers of local metallicities. Such an analysis is further complicated by the sensitivity of various metallicity calibrators to diffuse ionised gas (DIG) and low-ionization nuclear emission-line regions (LINERs). I will present indirect evidence of chemically-enriched winds within nearby AGN, LINERs and composites from the MaNGA-ARO Survey of CO Targets (MASCOT; Wylezalek et al. 2022) as they move towards the red cloud. Specifically, we find a strong link between gas-phase metallicity gradients and velocity broadening in the ionised gas phase within one half-light radius, which further coincides with reduced star formation efficiencies on galaxy-wide scales. We run a full spectral fitting procedure on the optical-IFU MaNGA data and investigate molecular gas properties from our single-dish CO observations to put the impact of outflows into context with the effects from in-situ star formation and gas accretion.

Detection of massive molecular and dust reservoirs around ~ 2 extremely red quasars: CGM enrichment by quasar-driven outflows

Jan Scholtz | KICC, Cambridge University

Abstract

Large scale outflows are believed to be an important mechanism in the evolution of galaxies, as they can both suppress and enhance star formation as well as eject gas from their host galaxies and mix the pristine gas from the intergalactic medium and processed material from the galaxy in the circum-galactic medium (CGM). We can study the impact of these large-scale outflows either by tracing the current outflows (by studying broad emission line profiles), or by studying the impact of past outflows on the gas surrounding the galaxy. In this work, we examined the CO(7-6), [CI](2-1), H2O (806 GHz) and dust continuum ALMA observations of 15 extremely red quasars (eRQSOs) at $z \sim 2.3$. By investigating the radial surface brightness profiles of both the individual sources and the stacked emission, we detect extended cold gas and dust emission on scales of ~ 14 kpc in CO(7-6), [CI](2-1), and dust continuum. We have further confirmed our results by investigating the visibilities of individual targets and the stacked visibilities. In this talk, I will compare the measured sizes and dust and cold gas masses of our detected halos with those from previous studies of cold gas halos around star-forming galaxies across redshifts 2–4 and discuss the impact of large scale outflows on the CGM around extremely powerful quasars.

The cold molecular gas kinematics of type-2 quasars as seen by ALMA.

Cristina Ramos Almeida | Instituto de Astrofísica de Canarias

Abstract

In this contribution I will present the first CO(2-1) and adjacent continuum observations of a small sample of seven nearby radio-quiet type-2 quasars (QSO2s) obtained with ALMA at ∼0.2" resolution (370 pc at z ∼ 0.1). Our CO kinematic analysis reveals that the QSO2s with higher Eddington ratios, which are hosted in spiral galaxies, have more massive and extended molecular outflows than the QSO2s in merging galaxies. Moreover, the ionized gas outflows in the spirals are almost coplanar with the CO disks (i.e., more favourable orientation for entraining the molecular gas), whereas those in the merging QSO2s subtend a relatively large angle. This could be contributing to drive more massive and extended molecular outflows in the spirals. These molecular outflows might be responsible for the smaller molecular gas concentrations measured in the central kpc (5-12% of the total gas mass), in comparison with the merging systems (18-25%). The radii ($r \leq 1$ kpc) and dynamical timescales of the outflows (∼1-11 Myr) are consistent with them being driven by the current AGN episode. These outflows represent 0.2-0.7% of the QSO2s' total molecular gas mass and have maximum velocities of 200-350 km/s and outflow rates of 8-16 Msun/yr. These outflow properties are intermediate between those of the mild molecular outflows measured for Seyfert galaxies and the fast and energetic outflows shown by ULIRGs. This suggests that it is not only AGN luminosity that drives massive molecular outflows. Other factors such as jet power, coupling between winds, jets, and/or ionized outflows and the CO disks, and amount or geometry of dense gas in the nuclear regions might also be relevant. Observations of quasar-driven molecular outflows are important because the constraints on mass-loss rates provided by observations of small ULIRG-dominated samples are biasing AGN feedback models towards extreme energetics that are not representative of the general AGN population.

The impact of active galactic nuclei on the molecular gas reservoir of their host galaxies at Cosmic Noon

Chiara Circosta | European Space Agency - ESAC

Abstract

AGN feedback is thought to be key in shaping the life cycle of host galaxies by injecting a significant amount of energy into the interstellar medium and potentially being able to suppress or inhibit future star formation through mechanisms such as outflows. This process is expected to be maximized at z∼2, the peak of supermassive black hole and galaxy assembly. Measuring the gas content out of which stars form is essential to understand the impact of AGN on star formation. So far, studies of AGN hosts at cosmic noon have been limited to inhomogeneous samples or bright objects. In this talk, I will present the first systematic study of the molecular gas content of AGN hosts at z∼2 for a representative and sizeable sample of 27 targets using ALMA observations of the CO(3-2) transition. When comparing the CO properties of AGN with a matched sample of non-AGN galaxies, we found indications that AGN feature lower CO luminosities, at given stellar masses and star-formation rates. I will explore the physical processes driving this finding with a particular focus on the role of ionized outflows in regulating the gas content in AGN, as traced by spatially-resolved VLT/SINFONI observations of the [OIII] line.

The impact of AGN outflows on star formation at cosmic noon using AO-assisted IFS observations

Darshan Kakkad | Space Telescope Science Institute

Abstract

Outflows in AGN host galaxies are believed to be a medium to shut off star formation by removing the gas supply. Both from observational and theoretical perspective, the existence of a direct evidence of negative or positive AGN feedback is highly disputed. We will present the spatially resolved Hα properties of 21 type 1 AGN host galaxies at cosmic noon derived from the SINFONI survey for Unveiling the Physics and Effect of Radiative feedback (SUPER). These AGN are known to host fast outflows in the ionised gas phase. The adaptive optics capabilities of SINFONI, a near-infrared integral field spectrograph, result in a spatial resolution of 0.2-0.3", equivalent to $\sim$2 kpc at the redshift of these galaxies. We carefully model the Hα line profile across every pixel in the SINFONI field-of-view to investigate the nature of the Hα emission i.e. whether it traces gas in the narrow line region or if it is associated with star formation. To do this, we first remove AGN contribution to the Hα emission to unveil extended emission from the host galaxy. Using resolved BPT diagrams, we verify that the narrow component of the extended Hα emission is most likely ionised by star formation in 50% of the galaxies. Furthermore, the spatial location of this unobscured star formation avoids the regions that show high outflows in the ionised gas traced by the [OIII]5007 emission, suggesting a negative feedback at play. We also discuss the significance of Hα emission as a tracer of ionised outflows in the narrow line region and how this affects previous literature results. This study has been performed for the first time for such a large sample of galaxies at cosmic noon with AO-assisted observations and provide strict constraints on the impact of AGN outflows on host galaxy star formation.

Finding AGN in gas-rich, star-forming galaxies does not rule out current AGN feedback models

Samuel Ruthven Ward | European Southern Observatory

Abstract

One of the most striking features of accreting SMBHs is their ability to influence the evolution of their host galaxy, launching large-scale outflows that can act to destroy or eject molecular gas, thus stifling the SFR of the galaxy. This negative feedback is often invoked as the main mechanism responsible for the quenching of massive galaxies and is built into the subgrid models of modern cosmological simulations. However, direct observational evidence of AGN feedback on a galaxy-wide scale is lacking. Observations tend to find that luminous AGN are located in gas-rich, star forming galaxies, seemingly in contradiction to what might be expected from this feedback theory. To address this apparent tension, I will present our investigation into the impact of AGN feedback on host galaxy properties in some of the current cosmological simulations (IllustrisTNG, EAGLE and SIMBA) including the post-processed models for molecular gas abundances. We perform tests similar to those frequently used by observers and find that despite having very different feedback models, the simulations are in qualitative agreement, predicting: (i) no strong negative trends between AGN luminosity and galaxy properties; (ii) that both high-luminosity and high-Eddington ratio AGN are preferentially located in galaxies with high molecular gas fractions and sSFR; and (iii) that the gas-depleted and quenched fractions of AGN host galaxies are lower than a control sample of non-active galaxies. These results are in qualitative agreement with observational samples at both cosmic noon (z$\sim$2) and the local Universe (z$\sim$0) and show that such findings are not in tension with the presence of effective AGN feedback. I will also present quantifiable differences between the predictions from the simulations, which could allow us to observationally test the different subgrid feedback models and improve the link between observations and simulations of SMBH accretion and feedback.

The correlation of AGN outflows with SFR suggests delayed AGN feedback

Jong-Hak Woo | Seoul National University

Abstract

We will present the main results from a series of studies searching for observational signatures of AGN feedback, using low-z AGNs. First, based on a large sample of SDSS type 1 and type 2 AGNs at $z < 0.3$, we find no direct evidence of suppressed star formation. While the sSFR of AGN galaxies with strong ionized gas outflows is comparable to that of main-sequence star-forming galaxies, non-outflow AGNs show much lower sSFR, implying delayed AGN feedback. Second, our IFU follow-up study of luminous AGNs shows that outflow is confined in a relatively small region, indicating a limited impact of AGN outflows. Star-formation or shock signatures are often detected at the edge of outflows, implying both negative and positive feedback for a given object. These results suggest no evidence of instantaneous feedback and the overall impact of outflows on star formation is rather limited.

B16 Mapping ionized gas outflows in multi-wavelength selected AGN from MaNGA

Marco Alfonso Albán Morales | Universität Heidelberg

Abstract

Feedback from active galactic nuclei (AGN), in the form of AGN-driven winds, is often invoked in cosmological simulations to regulate star formation. The physical details are not fully understood, and our observational studies are heavily influenced by selection effects. Integral field spectroscopy and precise AGN selection can ease this issue. Therefore, here we present an analysis of ionized gas kinematics for AGNs selected from a multi-wavelength approach. We use the 10.010 galaxies provided by the two-dimensional spectroscopy of SDSS-IV MaNGA. To capture potential outflow signatures, we used a multi-component fitting procedure on the [OIII]5007 emission line profile. Regardless of the AGN-selection technique, we find a larger fraction of high emission line-width measurements in AGN than in non AGN selected galaxies, suggesting that the former present stronger wind signatures. We show that among the differently selected AGN population, the average emission linewidth radial profile for AGN galaxies is similar, except for radio-selected AGNs, which we find to be lower. Further analysis will give us insights about how informative a given AGN-selection method can be when studying the impact of AGN feedback on galaxy evolution.

B17 Quantifying the impact of AGN-driven winds on the stellar populations of their host galaxies

Patricia Bessiere | Instituto de Astrofisica de Canarias (IAC)

Abstract

If AGN-driven winds directly impact the evolution of their host galaxies then we should expect to find evidence of suppressed or enhanced star formation in relation to matched inactive galaxies. I will present the initial results of our analysis of the stellar populations of the host galaxies of the 48 luminous, obscured AGN which form the QSOFEED sample. We also perform an identical analysis of a matched control sample and compare the prevalence of young stellar populations (YSP; tysp $<$ 100 Myr) in both groups. Although such large studies are important in understanding the global nature of this relationship, it is also important to make more detailed studies of individual objects to enable us to understand the mechanism by which AGN outflows may impact star formation. Therefore, I will also outline the results of our spatially resolved investigation into the well-studied type II quasar Markarian 34. Using spectral synthesis modelling, we determine the spatial distribution of the YSP and employ the [OIII]5007 emission line as a tracer of the warm ionised gas kinematics. We demonstrate a spatial correlation between the outer edges of the blue-side of the outflow and an enhancement in the proportion of the YSP flux, suggesting that the outflow is responsible for triggering star formation in this region. In regions with more highly disrupted gas kinematics, we find that the proportion of YSP flux is consistent with that found outside the outflow region, suggesting that the increased disruption is preventing a similar enhancement in star formation from occurring. Our analysis suggests that Mrk 34 is an example of quasar driven outflows simultaneously producing both positive and preventive feedback, further demonstrating the complex nature of the relationship between quasars and their host galaxies.

B18 Feeding AGN in the presence of strong Feedback: The Case Study of Centaurus A

Abhijeet Borkar | Astronomical Institute of the Czech Academy of Sciences

Abstract

AGN feedback plays a crucial role in the growth of supermassive black holes. By injecting a vast amount of energy in the form of intense radiation, jets, and outflows, the surrounding gas is heated and pushed away from the vicinity of the black hole. So how can the SMBH continue to feed and grow in the presence of strong feedback? To investigate this, I will present our multi-wavelength analysis of the closest radio-loud AGN with a prominent radio and X-ray jet, Centaurus A. We combine high-resolution ALMA and *Chandra* observations to study the circum-nuclear region of the source, focusing on the inner ∼200 parsec. The observations confirm the presence of hot and cold gas phases in the form of a hot X-ray emitting plasma surrounded by a cold CO-emitting molecular disc. To understand the interaction between the incident radiation and the surrounding circum-nuclear medium, we used the spectral synthesis code CLOUDY to perform photoionization calculations of the transfer of radiation through the matter for a wide range of temperature, density and irradiating spectral shapes. We show that the thermal instability arising from the interaction between the high-energy radiation from the nucleus and the ambient gas and dust naturally explains the observed multi-phase medium. Efficient cooling of the gas allows clouds of cooler gas to co-exist within the hot plasma, which eventually fall towards the center, feeding the AGN. Colder dusty molecular clouds have to exist away from the hot region to survive, correctly reproducing the ALMA and *Chandra* observations. Our work highlights the importance of thermal instabilities within the framework of black hole growth in the presence of strong feedback.

B19 Supermassive Black Hole Winds in X-rays

Marcella Brusa | Dipartimento di Fisica e Astronomia, University of Bologna

Abstract

SUBWAYS ("Supermassive Black Hole Winds in X-rays") is an international program designed to provide a unique observational framework to test the validity of physical models for Active Galactic Nuclei (AGN) outflows, and to ultimately understand their impact onto their host galaxies. Within this framework, we have been awarded a Large Program of1.4 Ms with XMM-Newton in AO18, to observe a representative sample of 17 objects at z=0.1-0.5, above the knee of the AGN luminosity function with the main goal of obtaining a statistically sound estimate of the duty cycle and physical parameters of ultra-fast outflows (UFOs). We present here the preliminary results from the data reduction and analysis of the AO18 XMM-Newton dataset, and the re-analysis of additional 5 archival sources. We find that absorption lines corresponding to highly ionised iron are detected in 7/22 sources at aPMC≥95% significance level and hence corresponding to ∼30% of the sample. The results of this work are consistent with those previously obtained in the local and high-z Universe, and independently provide a further support for the existence of highly ionised matter propagating at mildly relativistic speed (≥0.1c) in a considerable fraction of AGN in the intermediate Universe

B20 An Atlas of AGN Near-IR IFU Datasets: Circumnuclear Molecular, Ionized, and Coronal Gas in Seyfert Galaxies

Dan Delaney | University of Alaska Fairbanks

Abstract

Investigation into the central region of active galactic nuclei (AGN) is crucial to expanding our understanding of the mechanisms behind fueling of AGN and their connection to the greater galactic dynamics. We present an effort to catalog K-band integral field unit (IFU) data of the central 400 pc of over 90 unique nearby AGN, curated from OSIRIS/Keck and SINFONI/VLT archival datasets. This catalog includes AGN of various Seyfert type (1, 2, 1h, and the 1.1-1.9 range), redshifts $z < 0.035$, L14-195keV luminosities in the range of 41.1 to 44 keV, and line of sight absorbing column density NH ranging from 20 to 25 cm-2. The IFU datacubes, integrated K-band spectra, and 2D emission line maps for H2 1-0 S(1) (2.12 micron), [Si VI] (1.96 microns), and Brackett-Gamma (2.16 microns) will be made publicly available. Additionally, this study utilizes the increased statistics afforded by this large sample to identify trends in the properties of the circumnuclear gas with fundamental AGN properties. The H2 1-0 S(1), [Si VI], and Brackett-Gamma emission was analyzed to characterize the line luminosity, velocity dispersion, and kinematics of the gas within the central 400 pc of the AGN. This increased sample size suggests the potential emergence of a trend in circumnuclear gas properties with AGN luminosity and obscuration. Seyferts with higher L14-195keV luminosities tend to also have higher line luminosities, surface brightness, and velocity dispersion. Line luminosities and surface brightness are also higher within the central 200pc for Type 1.8-2 compared to Type 1-1.5 Seyferts in all three emission lines; no dependency of the velocity dispersion on Seyfert type is found. This sample provides supporting evidence that AGN feedback is more extreme in higher luminosity Seyfert galaxies, and that feedback processes influence the molecular, ionized, and coronal gas out to scales of at least the central 200pc.

B21 Central molecular gas depletion in AGN host galaxies - a smoking gun for kpc-scale feedback?

Sara Ellison | University of Victoria

Abstract

Galaxies have long been known to be distributed into two broad populations: star-forming, gas-rich disks and quiescent, gas-poor ellipticals. Understanding the mechanisms that cause the transition between these populations, and in particular the cause of star formation quenching, has been a major focus in extra-galactic astronomy in the last decade. The feedback effects of AGN have emerged as a compelling pathway to quenching, thanks to numerous pieces of observational evidence including 1) the commonality of outflows in AGN hosts, 2) inside out quecnhing profiles and 3) close correlations been quenching and black hole mass. However, detecting the direct impact of AGN feedback on the galactic gas reservoir (which must occur if star formation shuts down) has been observationally elusive, and most AGN host galaxies have normal (or even elevated) gas fractions. In this talk I will argue that the short-term impact of AGN feedback is spatially local in nature, hence difficult to detect in studies of global gas content. To demonstrate this, I will show kpc-scale molecular gas observations of 4 local Seyfert galaxies, all of which exhibit reduced central gas fractions. These observations represent a direct smoking gun for central AGN feedback.

B22 Linking [OIII] outflows in AGN to low-frequency radio emission: new observations with LOFAR

Emmy Escott | Durham University

Abstract

AGN (Active Galactic Nuclei) show signatures of outflows which have the potential to alter the evolution of the host galaxy, a process known as AGN feedback. However, we do not know exactly how AGN feedback operates. To further our understanding of these outflows, we must study what drives them. Previously, outflows have been linked to enhanced radio emission and I aim to investigate this connection using new observations at low frequency using LOFAR (Low Frequency Array). In this talk, I will present a sample constructed by cross-matching SDSS (Sloan Digital Sky Survey) Data Release 14 with the multi-wavelength catalogue from the LoTSS (LOFAR Two-meter Sky Survey) Deep Field survey of the Boötes field and the methods I used to analyze the link between outflows and radio properties in AGN. I fit the [OIII] 5007 emission line to investigate the kinematics of this emission line, its properties, and determine whether an outflow is present. Around 40 percent of the sample contains outflows at $z < 0.83$. I will show how [OIII] outflows correlates to the radio properties from LoTSS and look towards using sub-arcsecond resolution imaging with LOFAR to resolve the radio emission of the sample to several kpc to help understand its nature.

B23 The impact of multi-phase outflows and low power radio jets on the host galaxies of quasars

Aishwarya Girdhar | European Southern Observatory, Garching bei Munich

Abstract

AGN have become a fundamental ingredient in galaxy formation models to explain a wide range of galaxy properties. However, there is a lack of consensus for the most powerful AGN in how their outflows (e.g., radio jets/quasar winds) can impact the host galaxy's star formation (positive/negative/no feedback). We are performing a multi-wavelength study of 42 powerful $z < 0.2$ quasars to address these questions. This survey offers the benefit of studying high-luminosity quasars, which are representative of L^* at the peak cosmic epoch of growth (where quasar feedback is expected to dominate), while ensuring sub-kpc spatial resolution observations. The quasars of this survey, despite being moderately radio-luminous (radio-quiet, $L[1.4GHz] < 10^{25}$ W/Hz), show low-power radio jets driving multi-phase outflows over kiloparsec scales. I will present spatially-resolved (sub-kpc) kinematics of 9 target galaxies for the stellar component (from MUSE) and the gas component (ionized and molecular, from MUSE and ALMA), with imaging from VLA; to estimate in exquisite detail how the quasars interact with their host galaxies. We find that these jets have multiple impacts on the ISM, specifically: 1) radio jet-ISM interactions in both the ionized and molecular phases; 2) outflowing, dense, turbulent and multi-phase gas, perpendicular to the jet-axis, extending to galactic scales and; 3) evidence for jet-induced feedback on the stellar properties in sub-kpc scales. I will present these observational results with a discussion on the impact these processes may have on the short- and long-term star formation in the host galaxies and how this varies with the properties of the jets (e.g., inclination, power). I will place these results in the context of recent simulations that demonstrate how jets can both globally suppress and locally enhance star formation. Finally, I will argue that our results imply that the feedback from jets could be an important, previously underappreciated, feedback mechanism for bolometrically luminous radio-quiet quasars.

B24 Physics and Energetics of the Ultra Fast Outflow in IRAS F11119+3257

Giorgio Lanzuisi | INAF-OAS Bologna

Abstract

IRASF11119+3257 is a nearby ($z = 0.189$) Ultraluminous Infrared Galaxy with post-merger morphology, hosting a type-1 QSO ($L_{AGN} \sim 10^{46}$ erg/s). In 2015 this source made the Nature cover (Tombesi et al. 2015) as it was the first system in which it was possible to connect the nuclear outflow, observed with Suzaku, with a powerful galaxy-scale molecular outflow, observed in OH and CO transitions. In Nov. 2021 we finally obtained the first long look (120ks) for this target with XMM, complemented by simultaneous 50ks NuSTAR data. The ultra fast outflow at ~ 9.5 keV rest-frame energy ($v_{out} \sim 0.25$c) is seen by both XMM and NuSTAR with unprecedented details, and even resolved in two different velocity components. A strong P-Cygni profile indicative of a wide-angle outflow is observed for the first time in the soft band ($\sim$ 1 keV). Variability both in flux and absorption features' intensity is observed within the XMM observation. The unprecedented data quality allow us to test the most updated wind models and derive robust estimates of the energetics of the nuclear wind, that will be compared with the properties of the large scale outflow.

B25 The Impact of AGN on the molecular gas properties of quasar host galaxies

Stephen Molyneux | European Southern Observatory / Astrophysics Research Institute (LJMU)

Abstract

Galactic feedback processes are thought to regulate the observed co-evolution of accreting black holes and their host galaxy that is observed across cosmic time, but our understanding is still in its infancy. Molecular gas is the fuel for star formation in these galaxies and so it is crucial for understanding the impact of AGN on their host galaxy evolution. Therefore, analysing its relation to jets and outflows is an important avenue of research. I will present analysis of the molecular gas properties of an unbiased sample of 17 Type 2 quasars at $z < 0.2$, which are part of a wider multi-wavelength study to establish how quasars interact with their host galaxies. To establish the cold molecular gas properties we have observed the three lowest CO transitions in these quasar host galaxies using the ALMA Compact Array and APEX. We characterise the total molecular gas properties, including molecular gas masses and spectral line energy distributions (to determine the excitation of the gas). We investigate all of these properties as a function of in-hand radio and ionised gas observations from the VLA and MUSE, to study the effect of AGN feedback in the context of interactions between the molecular gas, ionised gas and observed radio jets. From this we have found evidence for radio jets lifting the molecular gas as well as a tentative relation between the shape of the CO spectral line energy distributions (SLEDs) and the radio and ionised gas properties.

B26 Quasars in the feedback phase: a new discovery space opened by eROSITA

Blessing Musiimenta | University of Bologna

Abstract

Theoretical models of the co-evolution of galaxies and AGN ascribe an important role to a short, luminous, and dust-enshrouded phase during which the accretion rate of the supermassive black hole is expected to be at its maximum. This "blow-out" phase is expected to be highly obscured in the IR band but only mildly obscured in the X-rays. In this talk, I will focus on the discovery space offered by large-area X-ray surveys to select these very rare sources. In particular, I will present new results from the eROSITA ∼140 square degrees eFEDS survey: the large area covered and the associated high-quality, multi-wavelength data led to the discovery of the largest number of candidates QSO in the feedback phase from a single survey (∼1000 sources). Available optical spectroscopy for a small subsample of them unambiguously confirms the presence of AGN-driven winds, in agreement with model predictions for objects in this rapid, transition phase. I will also discuss the correlations between AGN and wind properties obtained from our largest compiled sample of ionised AGN outflows.

B27 Unveiling accretion disc winds from supermassive black holes with Monte Carlo X-ray radiative transfer modelling

Hirokazu Odaka | The University of Tokyo

Abstract

An accretion disc wind with an velocity of 30% of the speed of light arising from a supermassive black hole, also known as an ultra fast outflow, was discovered as the third energy release mode of a black hole, after intense ultraviolet/X-ray radiation and a relativistic jet. This outflow can have a large impact on the surroundings with its enormous kinetic power, and is a candidate mechanism responsible for the AGN feedback. The outflow has been best studied in the X-ray band, observed as blue-shifted absorption lines of highly ionised ions. However, physical properties of the wind are extremely difficult to evaluate by conventional data analysis because of the absence of accurate X-ray spectral models. We have developed a novel three-dimensional X-ray radiative transfer simulation code, MONACO (HO et al. 2011), which can produce X-ray emission and absorption spectra from the photoionised plasma constituting a wind. The code calculates photon propagation and interactions with electrons and ions based on detailed atomic physics database and hydrodynamic structure. We have applied the model to the quasars PDS 456, APM 08279+5255, and PG 1211+143 (Hagino, HO et al. 2015, 2017; Mizumoto, HO et al. 2021), and establish a picture of disc wind accelerated by intense ultraviolet. We also find a spectral variability observed in a very short timescale of a few days can be attributed to local changes on the line of sight, revealing that the wind has inhomogeneous structure possibly generated by hydrodynamic instability. In this talk, we present the model framework and physics implementation, review the X-ray data analysis, and discuss the nature of the wind. In addition, we discuss prospects for the simulation-based analysis methods of the next-generation high-resolution X-ray spectroscopy with XRISM and Athena.

B28 Warm Absorbers in the Radiation-driven Fountain Model of Low-mass Active Galactic Nuclei

Shoji Ogawa | Kyoto University

Abstract

To investigate the origins of the warm absorbers in active galactic nuclei (AGNs), we study the ionization-state structure of the radiation-driven fountain model in a low-mass AGN (Wada et al. 20216) and calculate the predicted X-ray spectra utilizing the spectral synthesis code Cloudy (Ferland et al. 2017). The spectra show many absorption and emission line features originating in the outflowing ionized gas. The O VIII 0.654 keV lines are produced mainly in the polar region much closer to the supermassive black hole than the optical narrow-line regions. The absorption measure distribution of the ionization parameter (ξ) at a low inclination spreads over 4 orders of magnitude in ξ, indicating the multiphase ionization structure of the outflow, as actually observed in many type 1 AGNs. We compare our simulated spectra with the high energy resolution spectrum of the narrow-line Seyfert 1 galaxy NGC 4051. The model reproduces slowly outflowing (a few hundred km/s) warm absorbers. However, the faster components with a few thousand km/s observed in NGC 4051 are not reproduced. The simulation also underproduces the intensity and width of the O VIII 0.654 keV line. These results suggest that the ionized gas launched from subparsec or smaller regions inside the torus, which is not included in the current fountain model, must be an important ingredient of the warm absorbers with a few thousand km/s.

B29 The Role of AGN Feedback in Regulating the Growth of SMBHs

Scott Randall | Center for Astrophysics | Harvard & Smithsonian

Abstract

Over the past two decades, high spatial-resolution X-ray observations have made it clear that the most massive SMBHs, in galaxy clusters and groups, regulate their own growth via AGN feedback with the surrounding intracluster medium (ICM). However, the details of how the energy output of the SMBH couples to and heats the ICM, and how this heating affects the availability of cooler sub-keV gas to feed the SMBH, are still unclear. The decay of AGN driven turbulence, repeated outburst shocks, and mixing with the radio emitting plasma detected inside ICM cavities likely all play a role at some level, with the relative contributions possibly depending on the properties of the host cluster (e.g., mass, formation history, etc.). I will discuss recent results regarding the kinetic-mode AGN feedback loop, including results from deep observations of the unique galaxy group NGC 5813. This system contains three pairs of collinear cavities, each associated with a clear outburst shock, allowing a detailed comparison of the heating mechanisms at play in the same system.

B30 AGN Winds as Probed by Emission Lines, Absorption Features, X-rays, IR, and Radio

Gordon Richards | Drexel University

Abstract

Radiation-driven accretion disk winds may play an important role in the growth and evolution of active galaxies, yet it is not clear under what conditions these winds exist and the extent of their influence. This talk will explore the use of UV and optical emission lines, UV and optical absorption features, X-rays, infrared, and radio as diagnostics of accretion disk winds, exploring the extent to which luminosity and Eddington ratio are individually necessary, but insufficient conditions for the development of radiation-driven winds. Optical/UV emission-line properties of quasars are highly correlated, yet analyses of quasar spectra typically throw away most of the information available by measuring just a few line parameters of a few of the emission lines. Not only are emission-line properties correlated, but correlations between emission and absorption (including both NALs and BALs), and also X-ray, IR, and radio properties of quasars can be leveraged to enhance our knowledge of the prevalence and influence of winds. As relative orientation can distort our understanding of emission-line features, we will further explore a method for determining edge-on orientation in quasars. The strongest radiation driven winds seem to require both high luminosity and high Eddington ratio, thus we consider differences that can be expected in LSST, which will probe to lower luminosity and Eddington ratio than did SDSS.

B31 The AGN-galaxy interplay through spectral modeling and multiphase outflows

Alejandra Rojas | Universidad de Antofagasta (UA) / Universidad Diego Portales (UDP)

Abstract

High velocity (>1000 km s^{-1}) and extended AGN-driven outflows are frequently detected in local and high-redshift galaxies, at different luminosities, in ionized, neutral and molecular gas. However, despite the huge improvement in the knowledge of AGN-driven outflows, most of the samples considered by these studies are incomplete due to biases against absorption in the optical/soft X-ray band. Therefore it has been difficult to place the outflow signatures of galaxy populations in the context of both obscured and unobscured AGN. Hard X-ray selection of local AGN (>10 keV) allow us to study the occurrence of ionized outflows traced by the [O III]λ4959,5007 emission lines and how they relate to other key AGN properties (bolometric luminosity, Eddington ratio, column density, intrinsic X-ray luminosity). This sample is almost unbiased against obscuration or AGN types and covers a large range of luminosity, therefore the occurrence of outflows and its dependence with the different AGN power tracers is providing us a new point of view on the unification scenarios. Additionally, we present the incidence and properties of ionized outflows and how they relate, in terms of wind velocities, outflowing mass rate, and wind power, to the host galaxy properties by using a recently developed tool to analyze and characterize their host galaxies thanks to ancillary multi-wavelength data. Finally, we will present preliminary results on the properties of those outflows detected in the molecular phase, by searching for cold gas reservoirs.

B32 Mapping intrinsic Ly-alpha halos of high-redshift AGN with MUSE

Wuji Wang | Center for Astronomy of Heidelberg University

Abstract

High-redshift radio galaxies (HzRGs)are powerful AGN and are hosted by some of the most massive galaxies. They are surrounded by an enriched CGM allowing us to study feeding and feedback processes at and beyond Cosmic Noon. To understand the role of the CGM thoroughly, we observed a sample of eight HzRGs ($2.92 < z < 4.51$) with MUSE. In addition to the prominent Ly-alpha line, several UV emission lines (such as NV and CIV resonance lines) are also captured and also present clear absorption features. In our pilot study, we map the absorption corrected halo of the z∼4.5 redshift radio galaxy and find evidence that AGN feedback may play an important role in redistributing material and metals on large-scale environments (Wang et al. 2021). In my talk I will present the results of this technique applied to the full MUSE sample, i.e. mapping the intrinsic Ly-alpha emission halos of our HzRGs. The developed smoothing+tessellation technique for MUSE (or IFU) data allows us to capture faint emission and probe the largest halo extension (seven of our HzRGs have halo sizes > 100 kpc) only limited by the depth of the data. HI absorption features are often interpreted as real velocity structure or as radiative transfer effect. Seeing them in both hydrogen and metals, we argue that they are due to absorbing gas and must be considered in CGM analysis. In this way, we can decipher the morphological and kinematical information of the kpc-scale halos linking this with the feedback. Four of our MUSE targeted HzRGs will soon be observed with JWST/NIRSpec, which will enable us to explore feedback from the vicinity of the central engine and study its propagation through the host galaxy and beyond into the CGM at larger scales.

B33 Do Radio Jets Trigger Star Formation in High-redshift Radio Galaxies?

Belinda Wilkes | University of Bristol

Abstract

Understanding the impact of active galactic nuclei (AGN) on star formation (SF) in their host galaxies, an effect known as AGN feedback, is essential for a correct understanding of galaxy evolution. Feedback is also likely a major factor in causing SF and quasar activity to peak co-evally around z∼2 and decline in tandem thereafter. Despite these strong links, the specific mechanisms whereby a compact object can influence gas and SF on size scales billions of times greater than itself remain mysterious despite years of effort. A promising candidate physical scheme for feedback is one in which AGN-launched jets trigger transient bursts of SF in their host galaxies. Simulations of AGN jet heating of the intergalactic and inter-stellar media (ISM) imply strong—but transient—compression of the hosts' ISM by AGN jets. This results in an initial burst of SF which ages passively once the jet activity expands beyond the galaxy. This scenario has significant but so far inconclusive observational support, with evidence that short (young) jets in nearby AGN drive multi-phase outflows, and, at high redshift, the majority of Herschel-detected AGN, i.e. those with strong SF, tend to have shorter jets. I will report on the latest results of our multi-wavelength study, seeking both statistical trends and specific evidence for jet-ISM interactions in individual high-redshift ($1 < z < 2.8$) 3CR radio galaxies through submm (SMA, ALMA), radio, X-ray (Chandra), and optical (Hubble imaging, ground-based.spectroscopy).

R-B10 The Correlation of Outflow Kinematics with Radio Emission

Ashraf Ayubinia | University of Science and Technology of China

Abstract

We explore the relationship between the kinematics of ionized gas and radio activity using a sample of 6,000 optically-selected AGNs at z $<$ 0.4 with characterized [O III] profile and radio detection in the VLA FIRST Survey. We compare the correlation between ionized outflow kinematics and radio activity in different radio classes.We find no strong evidence of relationship between the [O III] velocity dispersion (normalized by stellar velocity dispersion) and radio emission. In contrast, we findthat the[O III] kinematics differ markedly for AGNs with high and low [O III] luminosity as well ashigh and lowEddington ratio.We also compare the relationship of ionized gas kinematics with jet kinematics (i.e., jet efficiency, normalized jet power and radio Eddington ratio) and Eddington ratio. We find that the most significant correlation stands for Eddington ratio. These findings suggest that accretion power is the primary mechanism in driving the extreme [O III] kinematics and radio jets may play a role as a secondary mechanism.

R-B11 Discovery of the radiatively-driven clumpy absorbers in the NLSy1 IRAS 13224-3809

Takuya Midooka | ISAS/JAXA, U. Tokyo

Abstract

Recent observational and theoretical studies suggest that most AGNs host various kinds of absorbers. For example, contemporary radiation-magnetohydrodynamic simulations indicate that the hot and strong accretion disk winds get unstable far from the central region and converted into gas clumps. These inner-wind and outer clumps may be actually observed as the ultra-fast outflows (UFOs) and the clumpy absorbers, respectively ("inner-hot outer-clumpy wind" model; Mizumoto et al. 2019). The UFOs are likely to contribute to the evolution of the SMBHs. However, it is challenging to place concrete observational limits on the origin of the UFOs and clumpy absorbers due to complications of the spectral variations. XMM-Newton observed the narrow-line Seyfert 1 (NLSy1) galaxy IRAS 13224-3809 in 2016 for 1.5 Ms, where extreme spectral variability and complex absorption features were recognized. We adopt a novel method, "spectral-ratio analysis", to resolve parameter degeneracy of the clumpy absorbers and other spectral components. As a result, we found that the soft spectral variation is mostly explained by a change of the covering fraction of the mildly-ionized clumpy absorbers, and these absorbers are outflowing with a velocity comparable to that of the UFO ($\sim$0.2-0.3c). We also found that the outflowing velocity increases with the intrinsic luminosity. These results suggest that the clumpy absorbers originate in the radiatively-driven wind, supporting the "inner-hot outer-clumpy wind" scenario. Our finding that the mildly-ionized clumpy absorber has an ultra-fast velocity will be a key for the AGN feedback study, even when the UFO feature is not detected.

R-B12 The kinetic feedback channel traced by the coronal gas in radio-weak Active Galactic Nuclei

Alberto Rodríguez-Ardila | Laboratório Nacional de Astrofísica

Abstract

The kinetic channel is usually regarded as the dominant feedback process in radio-galaxies. However, its effects in radio-weak AGN is still uncertain and poorly assessed. In this work, by means of the high-ionisation gas component, we trace the kinetic feedback in a sample of seven radio-weak bona-fide active galactic nucleus. We found that the [FeVII] λ 6087 and [FeX] λ6074 emission region extends to kiloparsec scales, allowing us to set new limits to the size of the coronal line region. In all cases, the high-ionization gas is strongly aligned to the radio-jet. Moreover, it is kinematically perturbed, and its morphology and extension coincides with that of the extended X-ray emission, suggesting that it is shock-driven and strongly associated to the radio-jet. Models combining the effect of photoionization by central source and shocks nicely reproduced the observed emission line strengths of both low- and high-ionization gas. The outflow rate and kinetic power derived for the sample show that the highly-ionized component maps best the kinetic channel and plays a very important role in the feedback process of radio-weak AGN.

R-B13 Impact of AGN feedback on SMBHs, galaxies and their multiphase ISM across cosmic time

Milena Valentini | Ludwig-Maximilians Universitaet, LMU/USM, Munich, Germany

Abstract

AGN (Active Galactic Nucleus) activity is observed across cosmic time. Observed multiphase outflows powered by AGN are a direct consequence of the fact that the energy generated by accreting supermassive black holes (SMBH) is coupled to the surrounding interstellar medium (ISM) in what is commonly referred to as AGN feedback. The role of AGN feedback is key in regulating the formation and evolution of galaxies. However, how SMBHs transfer feedback energy to the surrounding, multiphase ISM is still far from being fully understood and an accurate modelling in cosmological hydrodynamical simulations is still missing. In this talk, I will focus on the SMBH growth and feedback in a local, Milky Way-like galaxy and in host galaxies of high-redshift (z=6) quasars. I will discuss results from a suite of cosmological simulations, showing: (i) the impact of different models of gas accretion onto SMBHs; (ii) the effect of different ways of coupling AGN feedback energy to the multiphase ISM; (iii) how different models of gas accretion and coupling of AGN feedback energy affect the coevolution of SMBHs and their host galaxy. My simulations show that the SMBH activity can both quench (via gas heating) or enhance (by ISM over-pressurization) star formation. However, at least at $z > 6$, the galaxy star formation history is insensitive to such modulation as it is largely dominated by cold gas accretion from the environment that cannot be hindered by the quasar energy deposition. I will also show how AGN feedback contributes to drive galactic outflows, and discuss the key interplay between AGN and stellar feedback across cosmic time in cosmological simulations.

R-B14 Black Hole Masses from the OzDES Reverberation Mapping Project

Zhefu Yu | The Ohio State University

Abstract

Accurate mass measurements for supermassive black holes (SMBHs) are critical for understanding their growth over cosmic time and their co-evolution with their host galaxies. Outside of the local Universe, reverberation mapping (RM) of active galactic nuclei (AGNs) is the most accurate method for measuring SMBH masses. RM measures the time lag between the continuum and broad emission line region (BLR) variability of AGN, which gives the virial mass when combined with the broad line width. I will present the latest results from the Dark Energy Survey (DES) - Australian DES (OzDES) RM project, which monitored 771 AGNs for 6 years with weekly photometry and monthly spectroscopy. Our results include some of the highest-quality Mg II lags and a new relationship between the radius of the Mg II BLR radius and the continuum luminosity (R-L relation). The Mg II R-L relation is extremely important because it is widely used to estimate the masses for large numbers of SMBHs from single-epoch spectra and study the SMBH demographics, and our new relationship is derived from high-quality measurements at cosmic noon, the peak of AGN activity

Participant Directory

Nischal Acharya	Donostia International Physics Center
James Aird	University of Edinburgh
Marco Alfonso Albán Morales	Universität Heidelberg
David Alexander	Durham University
Rahma Alfarsy (Rem)	Portsmouth University
Lucas Almonacid (Rem)	Universidad de Concepción
Almudena Alonso Herrero	Centro de Astrobiología (CSIC-INTA)
Alba Vega Alonso Tetilla	University of Southampton
Tonima Tasnim Ananna	Dartmouth College
Carolina Andonie	Durham University
Daniel Anglés-Alcázar	University of Connecticut / Flatiron Institute
Sarah Appleby	University of Edinburgh
Roberto Assef	Universidad Diego Portales, Chile
Mathilda Avirett-Mackenzie	University of Bath
Ashraf Ayubinia (Rem)	University of Science and Technology of China
Mislav Balokovic	Yale University
Manda Banerji	University of Southampton
Amy Barger	University of Wisconsin-Madison
Cassandra Barlow-Hall	The University of Edinburgh
Ricarda Beckmann (Rem)	Institute of Astronomy, Cambridge
Jake Bennett	Centre for Astronomy, Harvard
Caroline Bertemes	Heidelberg University
Patricia Bessiere	Instituto de Astrofisica de Canarias (IAC)
Robert Bickley	University of Victoria
Keir Birchall	University of Leicester
Roger Blandford	Stanford University
Peter Boorman (Rem)	Astronomical Institute of the Czech Academy of Sciences
Abhijeet Borkar	Astronomical Institute of the Czech Academy of Sciences
William Brandt (Rem)	Penn State University
Marcella Brusa	Dipartimento di Fisica e Astronomia, University of Bologna
Johannes Buchner (Rem)	Max Planck Institute for Extraterrestrial Physics
Andrew Bunker	University of Oxford
Andreas Burkert	University of Munich
Lindsey Byrne	Northwestern University
Shoshannah Byrne-Mamahit	University of Victoria
Michael Calzadilla	MIT
Nico Cappelluti	University of Miami
Quinn Casey	Dartmouth College
Changhyun Cho (Rem)	New York University Abu Dhabi
Ena Choi	Korea Institute for Advanced Study
Hyunseop Choi	University of Oklahoma
Chiara Circosta	European Space Agency - ESAC
Andrea Comastri	INAF-OAS
Francoise Combes	Observatoire de Paris-Meudon
Tiago Costa	Max Planck Institute for Astrophysics
Timothy Davis	Cardiff University
Daniel Delaney	University of Alaska Fairbanks
Jack Delaney	University of Edinburgh
Ivan Delvecchio	INAF-Astronomical Observatory of Brera
Fabio Di Mascia	Scuola Normale Superiore
Tanio Díaz Santos	Institute of Astrophysics - FORTH
Sean Dougherty	Newcastle University

Participant Directory

Emmanuel Durodola	Dartmouth College
Sara Ellison	University of Victoria
Alice Eltvedt	Durham University
Emmy Escott	Durham University
Victoria Fawcett	Durham University
Román Fernández Aranda	European Southern Observatory
Nicolas Ferree	University of Richmond
Travis Fischer	Space Telescope Science Institute
Adi Foord	Stanford University
Sotiria Fotopoulou (Rem)	University of Bristol
Violeta Gámez Rosas	Leiden Observatory, Leiden University
Santiago García-Burillo	OAN-Spain
Isabelle Gauger (Rem)	Max Planck Institute for Extraterrestrial Physics
Dimitra Gerolymatou (Rem)	Université de Genève
Aishwarya Girdhar	European Southern Observatory
Eilat Glikman	Middlebury
Anniek Gloudemans (Rem)	Leiden Observatory
Mark Gorski (Rem)	Chalmers University
Karel Green	University of Nottingham
Kriti Kamal Gupta	Universidad Diego Portales, Santiago
Melanie Habouzit	ITA (Heidelberg University) and MPIA (Max Planck)
Chris Harrison	Newcastle University
Gabriel Roberto Hauschild Roier	Universidade Federal do Rio Grande do Sul
Erin Hicks	University of Alaska Anchorage
Ryan Hickox	Dartmouth College
Claire Hinrichs	Dartmouth College
Raphael Hviding	Steward Observatory
Zsofi Igo	Max Planck Institute for Extraterrestrial Physics
Dimitrios Irodotou (Rem)	University of Helsinki
Jacob Isbell	Max Planck Institute for Astronomy
Toshiya Iwata	The University of Tokyo
Takuma Izumi	National Astronomical Observatory of Japan
Stephanie Juneau	NOIRLab
Darshan Mahesh Kakkad	Space Telescope Science Institute
Changseok Kim (Rem)	Seoul National University
Dale Kocevski	Colby College
Rohit Kondapally	University of Edinburgh
Michael Koss	Eureka Scientific
Mirko Krumpe	Leibniz-Institute for Astrophysics Potsdam
Daniel Kynoch	University of Southampton
Brivael Laloux	Durham University / National Observatory of Athens
Erini Lambrides	NASA-Goddard
Lauranne Lanz	The College of New Jersey
Giorgio Lanzuisi	INAF-OAS Bologna
Marie Wingyee Lau (Rem)	University of California, Riverside
Mariana Lazarova	University of Northern Colorado
Karen Leighly	University of Oklahoma
Matías Liempi (Rem)	Universidad de Concepcíon
Paulina Lira (Rem)	Universidad de Chile
Iván López	Unibo-INAF
Vincenzo Mainieri (Rem)	European Southern Observatory
Umang Malik	Australian National University

Participant Directory

Filippo Mannucci	INAF - Arcetri
Summer McLaughlin	University of Sheffield
Takuya Midooka (Rem)	ISAS/JAXA, U. Tokyo
Marco Mignoli	INAF - Osservatorio di Astrofisica e Scienza dello Spazio di Bologna
Stephen Molyneux	European Southern Observatory / Astrophysics Research Institute
Leah Morabito	Durham University
Emily Moravec	Green Bank Observatory
Iván Muñoz Rodríguez (Rem)	National Observatory of Athens & University of Southampton
Lena Murchikova	Institute for Advanced Study & Harvard University
Blessing Musiimenta	University of Bologna
Shumpei Nagoshi	Kyoto University
Lubos Neslusan (Rem)	Astronomical Institute, Slovak Academy of Sciences
Qingling Ni	The University of Edinburgh
Hirokazu Odaka	The University of Tokyo
Shoji Ogawa	Kyoto University
Kyoko Onishi	Chalmers University
Silvia Onorato	Leiden University
Taira Oogi (Rem)	Ehime University
Natalia Osorio Clavijo	Instituto de Radioastronomía y Astrofísica UNAM
Hamsa Padmanabhan	Université de Genève
Priyanjali Patel (Rem)	Department of Astronomy, Universidad de Chile, Santiago
Pallavi Patil (Rem)	National Radio Astronomy Observatory
Giorgia Peluso	INAF-OAPD
James Petley	Durham University
Grayson Petter	Dartmouth College
Ryan Pfeifle	NASA Goddard Space Flight Center; George Mason University
Jonny Pierce	The University of Hertfordshire
Elia Pizzati	Leiden Observatory
Stephanie Podjed	Dartmouth College
Meredith Powell	Stanford University
Ragadeepika Pucha	University of Arizona
Cristina Ramos-Almeida	Instituto de Astrofísica de Canarias
Scott Randall	Center for Astrophysics | Harvard & Smithsonian
Amy Rankine	Institute for Astronomy, University of Edinburgh
Angelo Ricarte	Center for Astrophysics – Harvard and Smithsonian
Gordon Richards	Drexel University
Alberto Rodríguez-Ardila (Rem)	Laboratório Nacional de Astrofísica
Alejandra Rojas	Universidad de Antofagasta / Universidad Diego Portales
Jorge Saavedra (Rem)	Universidad de Concepcíon
Luca Sala	Universitäts-Sternwarte München - Fakultät für Physik der Ludwig-Maximilians-Universität
Jan-Torge Schindler	Leiden Observatory
Dominik Schleicher (Rem)	Universidad de Concepción
Jan Scholtz	KICC, Cambridge University
Matthew Selwood	University of Bristol
Francesco Shankar	University of Southampton
Yanlong Shi (Rem)	California Institute of Technology
Malgorzata Siudek	IFAE, Barcelona
Hannah Stacey	Max Planck Institute for Astrophysics
Marko Stalevski	Astronomical Observatory - Belgrade
Aaron Stemo	Vanderbilt University
Matthew Stepney (Rem)	University of Southampton
Sabrina Stierwalt	Occidental College

Participant Directory

Jiri Svoboda	Astronomical Institute of the Czech Academy of Sciences
Shenli Tang	University of Tokyo
Atsushi Tanimoto	Kagoshima University
Matas Tartėnas (Rem)	Center for Physical Sciences and Technology
Yuichi Terashima	Ehime University
Nicole Thomas	Durham University
Yoshiki Toba	National Astronomical Observatory of Japan
Benny Trakhtenbrot	Tel Aviv University
Yoshihiro Ueda	Kyoto University
Ryosuke Uematsu	Kyoto University
Hideki Umehata	Nagoya University
Milena Valentini (Rem)	Ludwig-Maximilians Universitaet, LMU/USM
Pierrick Verwilghen	European Southern Observatory
Bovornpratch Vijarnwannaluk (Rem)	Tohoku University
Carolin Villforth	University of Bath
Marta Volonteri (Rem)	Institut d'astrophysique de Paris
Wuji Wang	Center for Astronomy of Heidelberg University
Martin Ward	Durham University, UK
Samuel Ruthven Ward	European Southern Observatory
Clare Wethers	Instituto de Astrofísica de Canarias
Kelly Whalen	Dartmouth College
Belinda Wilkes	University of Bristol
Nico Winkel (Rem)	Max-Planck-Institut für Astronomie
Jong-Hak Woo	Seoul National University
Gabor Worseck	University of Potsdam
Dominika Wylezalek	University of Heidelberg, Astronomisches Rechen-Institut
Satoshi Yamada	RIKEN
Wei Yan (Rem)	Pennsylvania State University
Zhefu Yu (Rem)	The Ohio State University
Natacha Zanon Dametto (Rem)	IAC
Grisha Zeltyn	Tel Aviv University
Haowen Zhang	University of Arizona