'Early massive black holes as probes of cosmic structure formation (CosmicStruc)' Abstracts

Talks

The Cliff: Metallicity as a constraint on black hole evolutionary pathways in Little Red Dots

Authors
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Abstract
The James Webb Space Telescope (JWST) has revealed a large population of massive black holes (BHs) in the early Universe which are unexpectedly over-massive relative to their host galaxies. These findings have raised significant questions regarding black hole-galaxy co-evolution, and an observational approach will be key to understanding which models are realistic and for identifying the key mechanisms governing co-evolution. In this talk, I report the findings from recent high-resolution JWST/NIRSpec-IFS observations of The Cliff, a Little Red Dot (LRD) at z~3.5 first identified and characterised in the RUBIES survey (de Graaff+25). With these new observations, we detect narrow [OIII]4959,5007 emission which was unresolved by earlier JWST PRISM and medium-resolution observations, and find the weakness of [OIII]5007 relative to narrow Hbeta is indicative of low metallicity in the host galaxy (Z < 0.1 ZSun). I will show that the observed properties of the Cliff, including its overmassive black hole and low metallicity, can be reproduced by some simulations of black hole growth and evolution down to z~3.5 (AESOPICA, Koudmani+in prep.). However, these simulation runs require high seed masses (10^4 - 10^5 MSun) and appear as rarely in the simulation volume as in the 3<z<4 RUBIES survey volume, highlighting The Cliff as a rare system even under the most conservative estimates of BH mass. I will compare The Cliff to Abell2744-QSO1, a near-pristine LRD much earlier in cosmic time (z~7), and discuss how the metallicity of these unusual systems can constrain the underlying evolutionary pathways for the BHs they host. Finally, I will evaluate how future simulations and numerical models will help to uncover the mechanisms by which systems such as The Cliff manage to both grow massive black holes and remain so metal-poor across cosmic time.

The Impact of Dark Matter Models on Supermassive Black Hole Merger Rates and Pulsar Timing Array Observables

Authors

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Abstract

The connection between dark matter (DM) physics and supermassive black hole (SMBH) mergers has direct implications for gravitational-wave observatories such as Pulsar Timing Arrays (PTAs) and LISA. Recent PTA results indicate a substantial population of merging SMBH binaries at high redshift, while JWST observations suggest the existence of unexpectedly massive black holes in the early Universe. Together, these findings motivate a re-examination of how early-Universe structure formation shapes black hole growth.

In this work, we investigate how different dark matter models influence the assembly of halos, galaxies, and SMBHs, this manifests itself in their masses and abundances. The research I will be presenting involves running the DM simulations with the semi-analytical galaxy formation code Galacticus. After modelling the growth of structure, we introduced a "cosmology free" way to reliably convert the mass of our DM halos to SMBH masses, which enables us to construct black hole merger rates. Combining the mass and redshift data recovered from our simulations, with a measure of the source population distribution yielded predictions of the GW frequency from each merger. The GW frequency recovered from each of our DM models is then compared to extant PTA results and explore the event rates in the LISA detection band.

The significance of secular growth in galaxy-SMBH co-evolution in disk galaxies

Authors

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Abstract

There is a growing body of evidence that secular, merger-free growth mechanisms play a significant role in galaxy-SMBH co-evolution. Previous observational studies using small samples of rare "bulgeless" disk galaxies (with quiet merger histories) hosting broad-line AGN (BL-AGN) demonstrate galaxy-SMBH scaling relations persist in the absence of galaxy mergers. Subsequent cosmological volume simulations have also found that secular SMBH growth dominates over growth powered by galaxy mergers, on cosmic timescales. We have now selected a large sample of 2435 disk galaxies hosting BL-AGN in DESI, to investigate secular BH growth observationally on a larger scale. By performing bulge-disk decomposition, we isolate a sample of bulgeless disk galaxies more than five times larger than in previous studies.

Using Hα-based virial BH mass estimates, we investigate classical scaling relations for this sample. We present a fitted BH mass - stellar mass scaling relation for the largest sample of disk galaxies hosting AGN to date (log(MBH) = -3.7±0.3 + 1.00±0.03 log(Mstar)). The correlation between BH mass and stellar mass holds for bulgeless galaxies, indicating that co-evolution persists in secularly grown systems. We compare to a redshift- and mass-matched control sample of early-type galaxies hosting BL-AGN. We find that AGN hosted in early-type galaxies have higher observed bolometric luminosities than those hosted in their disk galaxy counterparts, but have statistically indistinguishable BH mass distributions. This suggests that the period of heightened BH accretion induced by galaxy merger activity in the early-types does not have a significant impact on the integrated accumulation of BH mass, supporting the results of simulations which find that secular mechanisms are dominant in the long-term growth of the BHs. Our results highlight the significance, even dominance, of secular BH growth in driving co-evolution.

Pulsar timing arrays and the cosmic evolution of massive black holes

Authors

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Abstract

Gravitational-wave astronomy offers a unique window on the assembly of massive black holes across cosmic time. Motivated by recent JWST discoveries of unexpectedly massive black holes in the early Universe, I will present an overview of how pulsar timing arrays probe the population of inspiralling supermassive black hole binaries through their nanohertz gravitational-wave emission. I will discuss the astrophysical insights that current PTA observations provide into black hole demographics, galaxy mergers, and the co-evolution of galaxies and their central black holes, and place these results in the broader context of future gravitational-wave observations both with PTAs and with LISA.