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Multiphase outflows in nearby active galactic nuclei observed with integral field spectroscopy

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The feedback from Active Galactic Nuclei (AGN) plays a pivotal role in the evolution of galaxies. Winds emanating from AGNs have the capability to expel gas from galaxies or redistribute it throughout the interstellar medium. These winds are observed in multiple gas phases, and we have systematically undertaken a study of the molecular and ionized phases of these winds in nearby AGNs using integral field unit spectroscopy. Our observations reveal that, overall, the outflows effectively redistribute the gas within the galaxy.

Recognizing and describing the processes that change galaxies from actively forming stars to being quiescent is a fundamental objective in extragalactic astronomy. One crucial mechanism driving this transformation is galactic-scale feedback resulting from active nuclei (AGN). Supermassive black holes (SMBHs - 10^6-10^{10} $M_\odot$) form early (as indicated by the observation of distant Quasars, for example), and they co-evolve with their host galaxies (Gebhardt et al., 2000; Ferrarese & Merritt, 2000). The feedback from Active Galactic Nuclei (AGN) plays a significant role in the evolution of the most luminous galaxies, preventing them from becoming overmassive (Silk & Mamon, 2012)

AGN winds are hardly resolved by observations of distant galaxies, where the bulk of galaxy/supermassive black hole growth occurs, but they can be resolved in nearby active galaxies. Our group has been studying the AGN feeding and feedback processes over 15 years, using optical and near-infrared integral field spectroscopy of inner kiloparsec of nearby active galaxies obtained with large telescopes. These observations are used to spatially resolve the molecular and ionized gas emission structure and kinematics. We find that while outflows in ionized gas are seen in most objects studied, in molecular gas they are are less common, which usually is dominated by rotation in the disk of galaxies and shows inflows in some cases.

Figure 1 illustrates the relationship between the kinetic power of ionized outflows and the AGN bolometric luminosity, utilizing results obtained by our research group alongside a compilation from the literature. Drawing a parallel between simulated injected energy and measured kinetic power in outflows is akin to comparing apples to oranges, as it is improbable that all the simulated energy translates directly into measured kinetic power (Harrison et al., 2018). In addition, the multi-phase nature of the AGN winds must also be taken into account. We find than the velocity of the outflows are usually lower than the escape velocity of the galaxies, but they are efficient in redistributing gas within galaxies, which will still be available for further star formation.

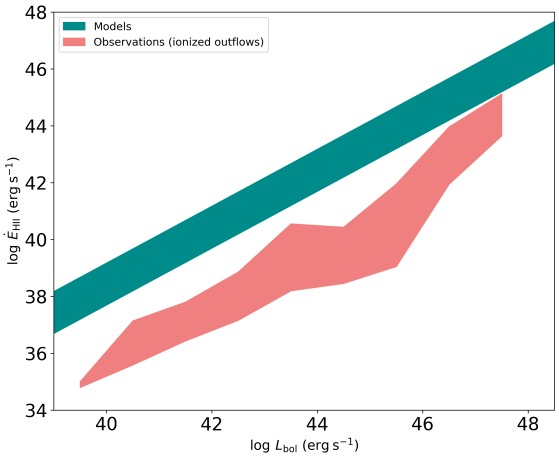

Figure 1. Plot of the kinetic power of the ionized outflows vs. the AGN bolometric luminosity using the data compiled by Riffel et al. (2023). The light red region depicts the average kinetic power of ionized outflows, along with the 1σ deviation, calculated within bins of 0.5 dex in AGN bolometric luminosity. The green region outlines the minimum efficiencies of outflow coupling required to effectively suppress star formation, as predicted by various simulations (Harrison et al., 2018).

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