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Resolving outflows and feedback in active galaxies with integral field spectroscopy

Feedback mechanisms from active galactic nuclei (AGNs) are considered to have a key role in the co-evolution between the central supermassive black hole (SMBH) and the host galaxy, being able to explain lots of observed galaxy properties. In particular, according to theoretical models, AGN-feedback is the main responsible for the quenching of star formation activity ('negative' feedback) in more massive galaxies, through either the heating or the ejection of the host galaxy gas by means of massive and fast outflows extending on galaxy-scales (~1-10 kpc).
From an observational point of view, AGN-driven outflows are routinely detected both locally and at high-z in different gas phases thanks to the advanced Integral Field Unit (IFU) spectrographs, which allow to obtain 2D-spatially resolved spectra and, hence, to spatially map the gas kinematics. However, even though observations have confirmed their existence in galaxies, two major aspects of AGN-outflows are still strongly debated: their acceleration mechanism and their actual impact on the host galaxy, especially their efficiency in suppressing the star formation in the host galaxy.
In the following, I will shortly describe the two main correlated research projects of my Ph.D. Thesis, aiming at investigating different aspects of galactic outflows, working with the Arcetri extragalactic group.

INAF-GTO on ERIS to investigate feedback and outflows in high-z QSOs. Thanks to the primary role of the Arcetri Astrophysical Observatory in the realization of the adaptive optics (AO) module of the instrument ERIS (Enhanced Resolution Imager and Spectrograph) for ESO/VLT, INAF will receive sixty nights of GTO time. Part of these nights will be devoted to the study of AGN-feedback processes and outflows. The operations of the new instrument at the VLT will start at the end of 2020 with the commissioning, and the GTO survey will start in 2021. I will collaborate with the Arcetri AO-group and join the ERIS commissioning.
In this framework, I will contribute specifically to the following research purposes:

- completing the study of the acceleration mechanism of ionized galactic outflows, started during my Master's Thesis, in the two faintest remaining QSOs observable from Paranal, located at $z\sim2$ and know to host X-ray ultra-fast outflows (UFOs) on the nuclear scale, that are the most promising 'engine' of large-scale AGN-winds (e.g. King 2010). The epoch $z\sim2$ is where are found the activity peak of both star formation and BH accretion histories (Madau & Dickinson 2014), hence where AGN-feedback is expected to be more effective. I will use the optical emission of the [OIII] line doublet as tracer of ionized outflows (e.g. Carniani et al. 2015; Cresci et al. 2015). Along with the results previously obtained in my Master's Thesis, these will extend the sample of well-studied QSOs known to host both UFOs and large-scale outflows, recently collected in Marasco et al. (2020). The final purpose is to shed light on the wind powering mechanisms and to test the predictions of current theoretical models (King & Pounds 2015).
- analyzing IFS data of the programmed survey of high-z QSOs selected to have existing ALMA interferometric CO-measurements, used as a proxy to measure the molecular H_2 gas content of the interstellar medium. This sample will allow to directly study for the first time the impact of AGN activity on the molecular gas reservoir of galaxies, which is the fuel used to form new stars, by comparing the H_2 content of host galaxies with and without prominent AGN-driven outflows. This will help in understanding how large-scale outflows cause the suppression of the star formation activity in the host galaxy, i.e. either mainly by sweeping the gas out of the galaxy or mostly by heating the gas through the injection of energy in the galactic interstellar medium, thus preventing the gas from cooling and forming stars ('ejective' vs 'preventive' feedback; e.g. Cresci & Maiolino 2018). For this purpose, in addition to the analysis of near-IR ERIS data tracing the ionized phase of outflows, I will analyze mm-data from the ALMA archive in order to detect the molecular gas through the CO-emission, from which to trace back to the H_2 gas mass (Solomon & Vanden Bout 2005).

Studying the various gas phases of outflows in NGC 6240. I will contribute to study galactic-wide outflows of different gas phases in NGC 6240, a prototypical nearby ultraluminous infrared galaxy (ULIRG) hosting two distinct AGNs. I will analyze IR data of NGC 6240 - already obtained - observed with the K-band Multi Object Spectrograph KMOS at the VLT, in order to access the additional IR diagnostic diagram for the shock excitation and ionization and to trace the neutral molecular phase outflow, using the IR emission of the H2 lines as tracers. The target has been observed with all the 24 configurable IFS arms of the multi-object spectrograph close to each other so as to provide a unique fully-sampled and extended (32.5″x16.3″) field of view, centered on the target. Additionally, the analysis of MUSE and ALMA archival data of NGC 6240 will allow to provide an unprecedented multi-wavelength IFU coverage and to detect, respectively, optical ionization tracers and the millimetric molecular CO emission, tracer of molecular gas. From that, it will be possible to identify the presence of both ionized and CO-molecular outflows.

References *(in order of appearance): King, 2010, MNRAS, 408, L95-L98; Madau & Dickinson, 2014, ARA&A, 52, 415-486; Carniani et al. 2015, A&A, 580, A102; Cresci et al. 2015, ApJ, 799, 82; Marasco et al. 2020, arXiv:2009.11294; King & Pounds 2015, ARA&A, 53, 115; Cresci & Maiolino 2018, Nature Astronomy, 2, 179-180; Solomon & Vanden Bout 2005, ARA&A, 43, 677; Feruglio et al. 2010, A&A, 518, L155; Cicone et al. 2014, A&A, 562, A21; Cicone et al. 2018, Nature Astronomy, 2, 176-178; Harrison et al. 2018, Nature Astronomy, 2, 198-205.*