*Galaxy Evolution and Feedback across Different Environments*
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# Gauging the effect of feedback from QSOs on their host galaxies

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**Abstract.** Often associated with the regulation of star formation in galaxies, active galactic nuclei (AGN) play a fundamental role in the evolution of galaxies through their feedback effects. To investigate the impact of these effects, we analysed the optical emission-line properties of 8 type II AGNs with bolometric luminosities $L_{Bol} > 10^{45}$ erg s$^{-1}$, using integral field spectroscopy (IFS) observations with Gemini Multi-Object Spectrograph (GMOS). The gas kinematics was obtained by fitting Gaussian components to the profiles of the emission lines of the ionized gas. Using only the broadest component – that we associate with the gas in outflow – we calculated the mass outflow rate ($\dot{M}_{out}$), finding values of up to 10 $M_{\odot}$ yr$^{-1}$. The outflow kinetic power ($\dot{E}_{out}$) reaches maximum values between $10^{41}$ and $10^{43}$ erg s$^{-1}$, which correspond to feedback efficiencies of ∼0.001−0.1 % of $L_{Bol}$. These values are below that required to quench the star formation during the evolution of galaxies in simulations and analytical models. We also investigated the effect of uncertainties on the values of the physical quantities used in the calculations – such as the electron density – on the final values of $\dot{M}_{out}$ and $\dot{E}_{out}$.

**Keywords.** galaxies: active, galaxies, kinematics and dynamics; quasars: emission lines

## 1. Introduction

AGNs are a major player in the evolution of galaxies, given the feedback energy released during the accretion of matter onto the central supermassive black hole of their host galaxies (Fabian 2012), where part of this energy couples with the local gas, lowering the star formation rate. The implementation of AGN feedback in cosmological simulations (e.g. Nelson *et al.* 2019) and semi-analytical models (e.g. Croton *et al.* 2016) is needed to reproduce some properties observed in the local Universe – such as the number of massive galaxies (Silk & Mamon *et al.* 2012). However, since simulations with different implementations can reproduce these results (Somerville & Davé 2015), it is important to use observations to constrain the recipes used in these studies.

*Sample*. To address this question, we studied the extended gas kinematics of a sample of 8 type II QSOs, with luminosities $10^{45.5} < L_{Bol} < 10^{46.5}$ erg s$^{-1}$ and $0.1 < z < 0.5$, using Gemini GMOS integral field spectroscopy, with the purpose of gauging the feedback power of the AGN via ionized gas outflows. These objects have extended narrow line regions (ENLRs) reaching distances beyond the limits of their host galaxies (Storchi-Bergmann *et al.* 2018; Fischer *et al.* 2018).

*Emission-line fitting*. We used multiple Gaussians to model the emission-line profiles of the ionized gas in the ENLR. In general, the broadest component – that we assumed is tracing an outflow – has high velocity dispersion (up to 750 km s$^{-1}$) and negative velocities relative to the systemic velocity. The additional narrower components show complex kinematics, consistent with the presence of interactions with nearby galaxies, previously observed in the Hubble Space Telescope images.

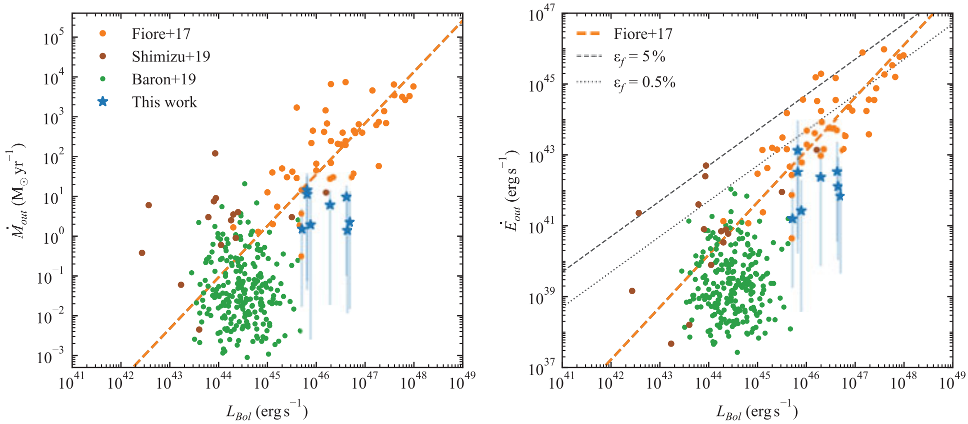


**Figure 1.** Mass outflow rate ($\dot{M}_{out}$, left) and outflow kinetic power ($\dot{E}_{out}$, right) as a function of the AGN bolometric luminosity. Blue stars: our data (with uncertainties due to different methods and assumptions). Orange circles and best-fit dashed lines: Fiore *et al.* (2017, ionized outflows). Brown circles: Shimizu *et al.* (2019). Green circles: Baron & Netzer (2019). Dotted and dashed black lines: outflow feedback efficiencies of 0.5 and 5 %.

## 2. Results

*Outflow properties*. Using only the broadest component, we calculated the mass outflow rates ($\dot{M}_{out}$) finding values of 1–10 $M_\odot$ yr$^{-1}$, with corresponding outflow kinetic powers ($\dot{E}_{out}$) reaching values between $10^{41}$ and $10^{43}$ erg s$^{-1}$. On average, these values are below previous ones from the literature for the same AGN luminosity ($L_{Bol}$) range (see Fig. 1).

*Uncertainties*. Testing the effect of different methods/assumptions used to obtain the outflow properties, we found that they can lead to a variation of 2–3 orders of magnitude in the final values of $\dot{M}_{out}$ and $\dot{E}_{out}$ (errorbars in Fig. 1). In particular, using higher densities (Baron & Netzer 2019) these quantities decrease by a factor of up to 100.

*Feedback efficiency ($\varepsilon_f = \dot{E}_{out}/L_{Bol}$)*. These are in the range 0.001–0.1 %, below those found to be able to quench star formation in simulations (e.g. Hopkins & Elvis 2010). However, our calculations consider only the contribution from the ionized gas to the outflow power, which may represent only a fraction of the total feedback power (Harrison *et al.* 2018).

## References

Baron, D. & Netzer, H. 2019, *MNRAS*, 486, 4290
Croton, D. J., Stevens, A. R. H., Tonini, C., *et al.* 2016, *ApJS*, 222, 22
Fabian, A. C. 2012, *ARA&A*, 50, 455
Fiore, F., Feruglio, C., Shankar, F., *et al.* 2017, *A&A*, 601, A143
Fischer, T. C., Kraemer, S. B., Schmitt, H. R., *et al.* 2018, *ApJ*, 856, 102
Harrison, C. M., Costa, T., Tadhunter, C. N., *et al.* 2018, *Nature Astronomy*, 2, 198
Hopkins, P. F. & Elvis, M. 2010, *MNRAS*, 401, 7
Nelson, D., Pillepich, A., Springel, V. *et al.* 2019, *MNRAS*, 490, 3234
Shimizu, T. T., Davies, R. I., Lutz, D., *et al.* 2019, *MNRAS*, 490, 5860
Silk, J. & Mamon, G. A. 2012, *RAA*, 12, 917
Somerville, R. S. & Davé R. 2015, *ARA&A*, 53, 51
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