Galaxy Evolution and Feedback across Different Environments
Proceedings IAU Symposium No. 359, 2020
T. Storchi-Bergmann, W. Forman, R. Overzier & R. Riffel, eds.
doi:10.1017/S1743921320004196

HST observations of [O III] emission in nearby QSO2s: Physical properties of the outflows

Anna Trindade Falcao[1], S. B. Kraemer[1], T. C. Fischer[2], D. M. Crenshaw[3], M. Revalski[2] and H. R. Schmitt[4]

[1]Institute for Astrophysics and Computational Sciences, Department of Physics, The Catholic University of America, Washington, DC, USA

[2]Space Telescope Science Institute, Baltimore, MD, USA

[3]Department of Physics and Astronomy, Georgia State University, Atlanta, GA, USA

[4]Naval Research Laboratory, Washington, DC, USA

Abstract. We used Space Telescope Imaging Spectrograph (STIS) long slit medium-resolution G430M and G750M spectra to analyze the extended [O III] λ5007 emission in a sample of twelve QSO2s from Reyes *et al.* (2008). The purpose of the study was to determine the properties of the mass outflows and their role in AGN feedback. We measured fluxes and velocities as functions of deprojected radial distances. Using photoionization models and ionizing luminosities derived from [O III], we were able to estimate the densities for the emission-line gas. From these results, we derived masses, mass outflow rates, kinetic energies and kinetic luminosity rates as a function of radial distance for each of the targets. Masses are several times 10^3-10^7 solar masses, which are comparable to values determined from a recent photoionization study of Mrk 34 (Revalski *et al.* 2018). Additionally, we are studying the possible role of X-ray winds in these QSO2s.

Keywords. galaxies: active, galaxies: QSO2, galaxies: kinematics and dynamics

1. Introduction

Accreting supermassive black holes (SMBHs) are believed to be the central engines that power luminous AGNs. The ionizing radiation released by the SMBH interacts with the interstellar medium of the host galaxy which may regulate the SMBH accretion rate and evacuate star-forming gas from the host galaxy bulge, i.e. AGN feedback. AGN winds are present in most AGNs (Mullaney *et al.* 2013). Recent studies (Fischer *et al.* 2018) question whether these winds produce efficient feedback. Determining this requires characterizing their physical properties, such as mass, mass outflow rates, kinetic energies and kinetic luminosity rates.

2. Sample, Observations and Calculations

In order to study the physical properties of these QSO2s, we have obtained Hubble Space Telescope (*HST*) imaging and spectroscopy of 12 of the 15 most luminous targets from Reyes *et al.* (2008) sample under z = 0.12 (Fischer *et al.* 2018) to map [O III] velocities and widths as a function of radial distance and determine physical properties of each system. To analyze and determine the number of significant kinematic components for each emission line, we used a fitting technique (Fischer *et al.* 2017), which gave

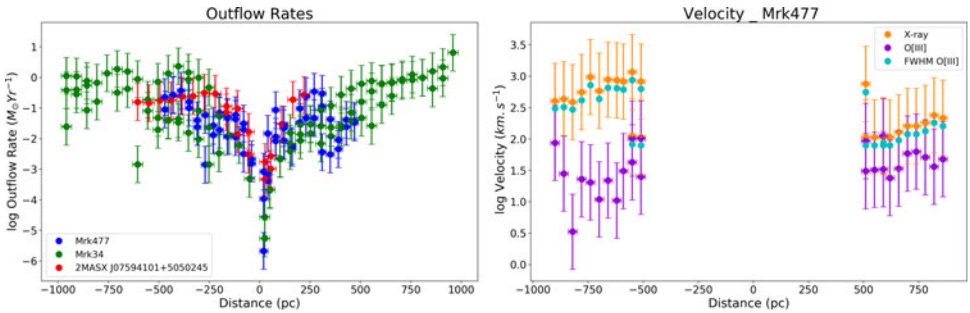

Figure 1. The left panel shows the mass outflow rates in units of $M_\odot\ yr^{-1}$ for Mrk 477, Mrk 34 and 2MASX J075941 as a function of distance from the nucleus. The right panel shows a comparison between the velocity profiles of the [O III] winds and X-ray winds, obtained using our method described in section 3, and the FWHM, for Mrk 477.

us [O III] fluxes and velocities (v) as a function of position. We used Cloudy models, a software designed to simulate conditions in interstellar matter under a broad range of conditions (Ferland *et al.* 2017), to derive the column densities and gas densities, at each de-projected distance from the nucleus (Trindade Falcao et al. in preparation).

Along the *HST* STIS slit, we calculated the gas mass as a function of distance from the nucleus using the observed [O III] fluxes as compared to those of the Cloudy model. The ionized gas mass as a function of distance from the nucleus, and M_{ion}, the total mass of ionized gas derived from the [O III] images, were calculated as described in Crenshaw *et al.* (2015). Using M_{ion} and v, we calculated the mass outflow rates ($\dot{M}_{out}$), kinetic energies (E), and kinetic luminosity rates ($\dot{E}$) (Figure 1, left panel). Among the QSO2s in our sample, the outflow region contains a total M_{ion} ranging from $5 \times 10^3 M_\odot$ to $1.10 \times 10^7 M_\odot$. The maximum E for the targets varies from 4.1×10^{50} to 1.96×10^{54} erg and the $\dot{M}_{out}$ peaks vary from $7 \times 10^{-3} M_\odot\ yr^{-1}$ to 4.15 $M_\odot\ yr^{-1}$. The peak $\dot{E}$ ranges from 1.00×10^{38} to 1.51×10^{42} $erg\ s^{-1}$.

3. Discussion and Conclusions

The maximum kinetic luminosity of the outflow for our sample reaches 6.56×10^{-9} to 8.04×10^{-4} of the AGN L_{bol}, which does not approach the 0.5%−5% range used in some models as providing efficient feedback (Di Matteo *et al.* 2005; Hopkins & Elvis 2010), **indicating that the [O III] winds are not an efficient feedback mechanism**, based on this criterion. Fischer *et al.* (2018) show that the outer regions of these QSO2s present disturbed gas with high FWHM. Assuming that the FWHM is due only to motion within the [O III] emission-line gas and to explore the possible causes of this disturbance, we calculated the kinetic energy density, U_{KE}, of the disturbed gas. If the disturbance is due to the impact of X-ray winds, they would have the same U_{KE} as the [O III] gas (Trindade Falcao *et al.* in preparation). This analysis made it possible for us to construct a velocity profile of these X-ray winds (Figure 1, right panel).

References

Crenshaw, *et al.* 2015, *ApJ*, 799, 83
Di Matteo, *et al.* 2005, *Nature*,433, 604
Ferland, *et al.* 2017, *RMxAA*, 49, 1379
Fischer, *et al.* 2017, *ApJ*, 834, 30
Fischer, T. C., Kraemer, S. B., Schmitt, H. R., *et al.* 2018, *ApJ*, 856, 102

https://doi.org/10.1017/S1743921320004196 Published online by Cambridge University Press

Hopkins & Elvis 2010, *MNRAS*, 401, 7
Kraemer, *et al.* 2000, *ApJ*, 532, 256
Mullaney, *et al.* 2013, *MNRAS*, 433, 622
Revalski, M., Crenshaw, D. M., Kraemer, S. B., *et al.* 2018, *ApJ*, 856, 46
Reyes, *et al.* 2008, *AJ*, 136, 2373