Some general considerations

The sizes of the HIP, MIP and LIP in units of the Schwarzchild radius $R_s = 2GM_{BH}/c^2$ are $R_{HIP} = (0.003 - 2.5) \times 10^3\ R_S$, $R_{MIP} = (0.057 - 4.8) \times 10^2$ $R_S$and $R_{LIP} = (0.25 - 2.8) \times 10^4\ R_S$.

Furthermore, following [5] we estimate the line-of-sight thickness given by $\Delta R \sim N_H/n_H$, and the relative value $\Delta R/R$. Using the approximation for a fully ionized gas of solar abundance on gets $\Delta R/R = 1.23 N_H (n_e R^2)^{-1/2} (n_e)^{-1/2}$. In this case we obtain $(\Delta R/R)_{HIP} = (0.001 - 1) \times 10^{-3}$, $(\Delta R/R)_{MIP} = (0.04 - 5) \times 10^{-5}$ and $(\Delta R/R)_{LIP} = (0.2 - 2) \times 10^{-4}$.

Implications for AGN feedback models

Here we comment on the potential implications of the values found for the warm absorber winds in driving the evolution of its host galaxy NGC3783. Our objective is not to derive a physical model for the winds, but instead discuss the values obtained in the context of recent theoretical developments on the physics of AGN feedback. We now present three relevant facts derived from our observations to present this discussion.

The first relevant fact derived from our results is that the location of the different ionization regions, R, are close to the black hole with distances less than a few thousands R_S. This is a hint that the physics of this region are dominated by winds driven by the accretion disc around the black hole [6]. The second fact is that the sizes of these regions ΔR with respect to their location is very narrow, on the order of $\Delta R/R \sim 10^{-5}$. The third important fact is that the mean values of the kinetic luminosities and the momentum fluxes computed over all the lines are on the order of $\dot{E}_k/L_{\rm bol} = (2 - 8)\%$ and $\dot{P}/(L_{\rm bol}/c) \sim 0.5 - 2$, this is presented in Figure 1, where we have used a value of $L_{\rm bol} = 1.5 \times 10^{43}$ erg s^{-1} [7].

Recently [4] gave an explanation for the low values of $\Delta R/R$ adducing a physical mechanism where the AGN blast impacts moderately dense interstellar gas clumps along the line of sight, fragmenting the clumps and sweeping them along the hot blast. From these model they predict values for the kinetic luminosities and the momentum fluxes of the order of $\dot{E}_k/L_{\rm bol} = (2 - 5)\%$ and $\dot{P}/(L_{\rm bol}/c) \sim 2 - 15$. Other models such as the cold thin shell approximation predict order of magnitude lower values for the kinetic luminosities. This gives a hint that such process might be at play in the case of NGC-3783.

The values we infer for the kinetic luminosities and the momentum flux are in the ballpark of required values to generate an observable effect on the evolution of the host galaxy [2, 1]. If we now consider that the outflow are in a energy conserving phase the relationship between the energy of the inflow wind and the swept up gas follows

$$\frac{1}{2}\dot{M}_{\rm in} v_{\rm in}^2 \approx \dot{M}_{out} v_{out}^2, \tag{1}$$

where the subscript *in* refers to the wind input values and *out* to the outflow

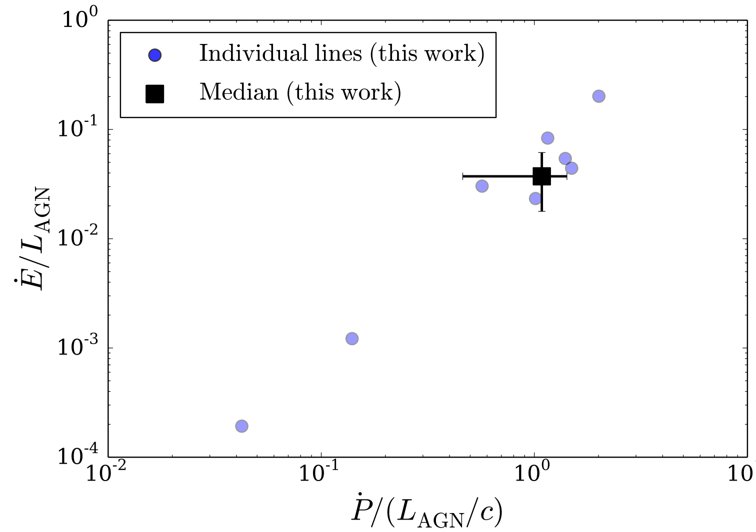

Figure 1: Kinetic luminosities and momentum flux for the different absorption features in the spectrum. The values are consistent with theoretical requirements to have an noticeable impact on the evolution of the host galaxy as suggested by AGN feedback simulations .

measured by the absorption lines. This means that roghly half of the kinetic if the input wind is converted into bulk motion of the setp-up gas [3]. From that relatinship on can infer the escaling for the input and outflow momentum flux $\dot{P}_{out}/\dot{P}_{in} \approx 1/2 v_{in}/v_{out}$. Assuming a value of $v_{in} = 0.1c$ and $P_{in} = L_{\rm AGN}/c$, we obtain the prediction

$$\frac{\dot{P}}{L_{\rm AGN}/c} = \frac{1}{2} 0.1 c v_{\rm peak}. \tag{2}$$

In Figure 2 we plot this prediction as a continuous line, compared to the values inferred in this paper. We find that there is a reasonable agreement for the median of the velocities measured from different features in the absorption spectra. We note that the same prediction for an energy conserving outflow provides a good fit to outflow measurements of ultraluminous infrared galaxies (ULIRGS) and FeLoBALs [3].

In summary, the results in NGC3783 are consistent with a physical picture where the warm absorber winds are in a energy conserving phase dominated by winds of velocities $0.1c$ injected close to the accretion disc region. Furthermore, the values for the momentum flow and kinetic luminosities suggest that the outflows will have a noticeable impact on the evolution of the host galaxy.

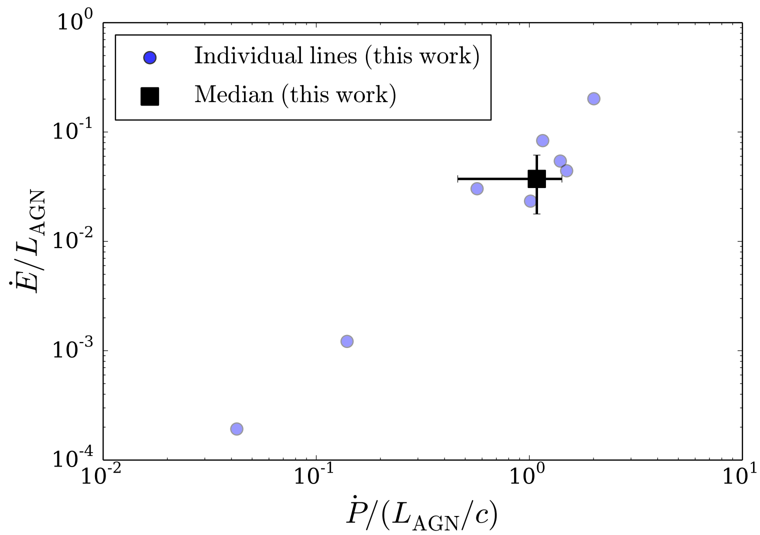

Figure 2: Momentum flux as a function of the peak velocities of different absorption features. The line shows the prediction for winds in an energy conserving phase that were injected at velocities $\sim 0.1c$.

Bibliography

[1] J. Debuhr, E. Quataert, and C.-P. Ma. Galaxy-scale outflows driven by active galactic nuclei. *MNRAS*, 420:2221–2231, March 2012.

[2] T. Di Matteo, V. Springel, and L. Hernquist. Energy input from quasars regulates the growth and activity of black holes and their host galaxies. *Nature*, 433:604–607, February 2005.

[3] C.-A. Faucher-Giguère and E. Quataert. The physics of galactic winds driven by active galactic nuclei. *MNRAS*, 425:605–622, September 2012.

[4] C.-A. Faucher-Giguère, E. Quataert, and N. Murray. A physical model of FeLoBALs: implications for quasar feedback. *MNRAS*, 420:1347–1354, February 2012.

[5] Y. Krongold, F. Nicastro, M. Elvis, N. Brickhouse, L. Binette, S. Mathur, and E. Jiménez-Bailón. The Compact, Conical, Accretion-Disk Warm Absorber of the Seyfert 1 Galaxy NGC 4051 and Its Implications for IGM-Galaxy Feedback Processes. *ApJ*, 659:1022–1039, April 2007.

[6] N. Murray, J. Chiang, S. A. Grossman, and G. M. Voit. Accretion Disk Winds from Active Galactic Nuclei. *ApJ*, 451:498, October 1995.

[7] H. Netzer, S. Kaspi, E. Behar, W. N. Brandt, D. Chelouche, I. M. George, D. M. Crenshaw, J. R. Gabel, F. W. Hamann, S. B. Kraemer, G. A. Kriss, K. Nandra, B. M. Peterson, J. C. Shields, and T. J. Turner. The Ionized Gas and Nuclear Environment in NGC 3783. IV. Variability and Modeling of the 900 Kilosecond Chandra Spectrum. *ApJ*, 599:933–948, December 2003.