Evidence of a clumpy disc-wind in the star forming galaxy MCG–03–58–007

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Introduction

Since the first detection of resonance iron K shell absorption lines blueshifted to rest-frame energies of E > 7 keV in luminous AGN (Reeves et al. 2003, ApJ, 593, 65; Pounds et al. 2003, MNRAS, 345, 705), high velocity outflows have become an essential component in the overall understanding of AGN. Systematic studies showed that the fast disc-winds are present in ~ 40% of the bright AGN (Tombesi et al. 2010, A&A, 521, 57; Gofford et al. 2013, MNRAS, 430, 60) suggesting that their geometry is characterized by a wide opening angle, as confirmed in the luminous quasar PDS 456 by Nardini et al. (2015, Science, 347, 860). These winds are considered the key ingredient of AGN feedback models and might represent the missing link in the observed galactic feedback process, by driving massive molecular outflows out to large (~kpc) scales in galaxies (Cicone et al. 2014, A&A, 562, 21; Tombesi et al. 2015, Nature, 519, 436; Feruglio et al. 2015, A&A, 583, 99).

MCG–03–58–007 is a nearby (z = 0.0315) bright Seyfert 2 galaxy. It was first selected as a Compton-thick AGN (i.e., $N_H > 10^{24}$ cm^{-2}) candidate due to its faint X-ray flux (Severgnini at al. 2012, A&A, 542, 46) as measured in a 10 ksec observation with *XMM-Newton* in 2005. A more recent 130 ksec simultaneous *XMM-Newton* & *NuSTAR* observation confirmed the presence of the wind and showed a rapid N_H variation on timescale of ~ 1 day (Braito et al. 2018, MNRAS, 479, 3592).

Here we report the results of a detailed analysis of a deep simultaneous 130 ksec *XMM-Newton* & *NuSTAR* observation of MCG–03–58–007, where we tested a clumpy torus as an alternative scenario for the observed variability. To this end we adopted the MYTorus model (Murphy & Yaqoob 2009, MNRAS, 397, 1549) for the toroidal reprocessor and assumed the decouple configuration, where the line off sight N_H is different from the global N_H (see Yaqoob 2012, MNRAS, 423, 3360). Nonetheless the signature of a powerful disc-wind is still apparent at higher energies and the observed rapid short-term X-ray spectral variability is more likely caused by a variable zone of highly ionized fast wind rather than a neutral clumpy medium.

NuSTAR lightcurve

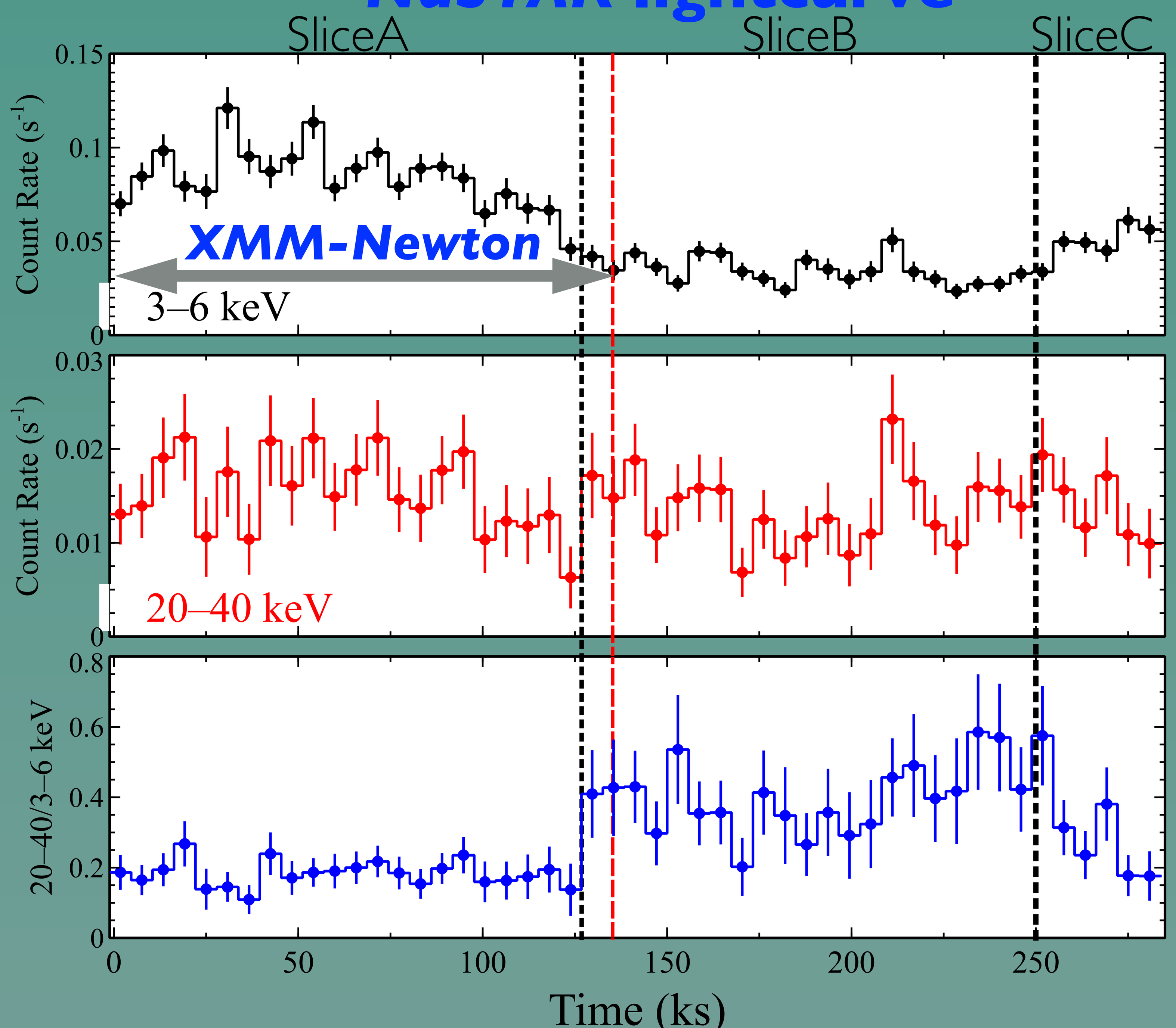

Figure 1. *NuSTAR* light curves extracted (with a bin-size of 5814 sec) in the 3–6 keV (upper panel) and the 20-40 keV band (middle panel). The lower panel shows the HR light curve defined as CR20–40keV/CR3–6keV. While there are only small fluctuations in the 20–40 keV light curve, the 3–6 keV light curve presents a sharp drop at around 125 ksec (marked with the black dashed line) into the observation and a smooth increase at the end of the observation (at around 250 ksec, black dashed line). The HR light curve (lower panel) shows a sharp increase at 125 ksec, suggesting that we are witnessing an obscuration event. At 250 ksec the HR starts to decrease to almost the initial value. The red dashed line marks the end of the XMM-Newton observation at around 140 ksec.

Multi-phase disc-wind in MCG–03–58–007

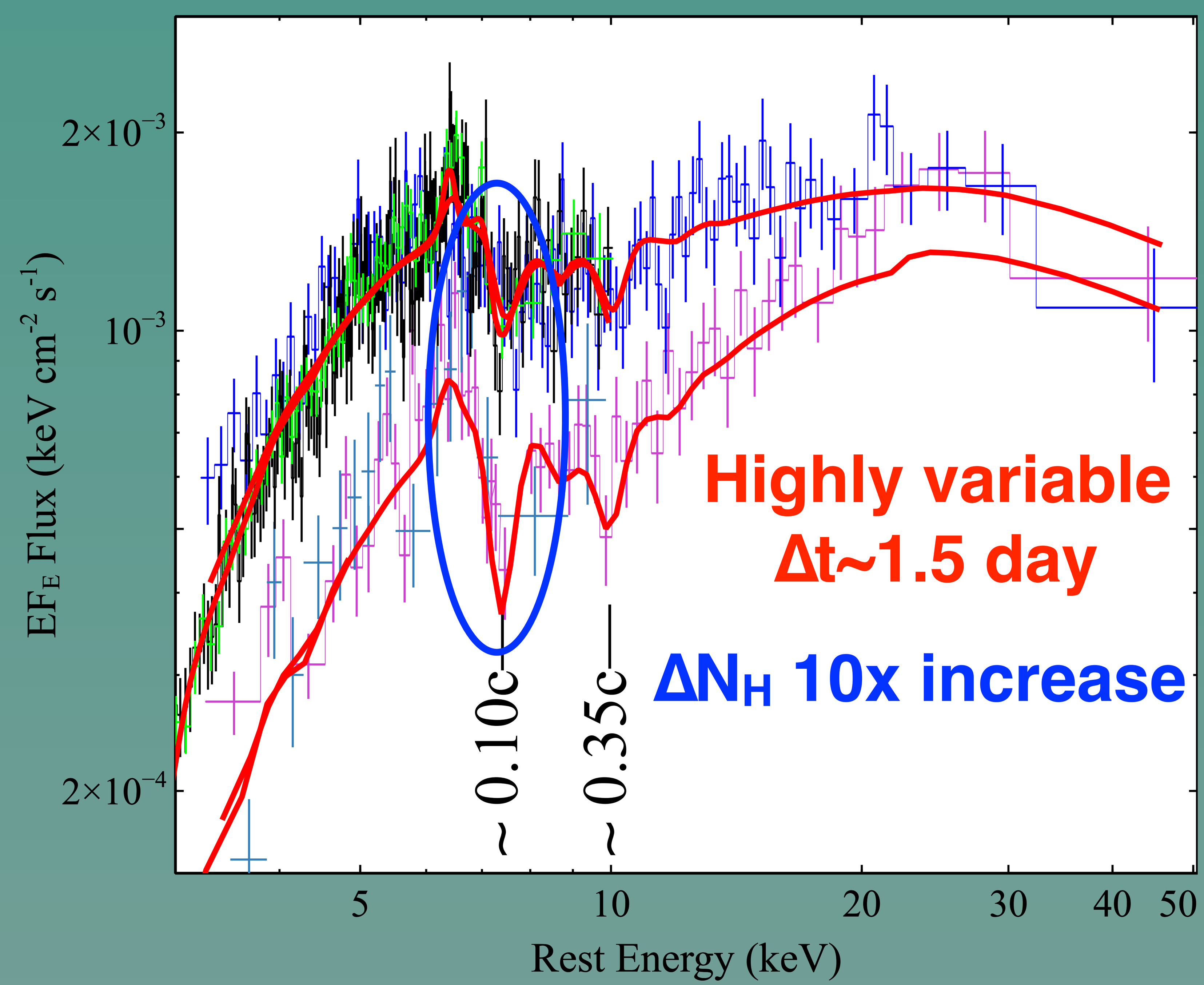

Figure 2. *XMM-Newton & NuSTAR* Slice A and Slice B spectra. Both spectra correspond to the first (pn black, MOS1+2 green and NuSTAR FPMA+B blue) and second (pn light blue and NuSTAR FPMA+B magenta) part of the observation respectively. The solid red line overlaid is the best-fit composed by MYTorus (for the toroidal neutral absorber) and a variable disc-wind (for the highly ionized wind) component. The disc-wind component requires (>99.99% c.l.) two zones of low (v/c ~ 0.1, zone1) and high (v/c ~ 0.35, zone2) ionized absorbers. Zone 1 is the main driver for the pronounced spectral curvature observed below 20 keV during the second half of the observation with a rapid increase in column density of $\Delta N_H \sim 1.4 \times 10^{24}$ cm^{-2}.

Time Resolved Spectral Analysis

MYTorus Decoupled i.e., Clumpy Torus

Wind: Nh is not variable **Wind: Nh is variable**

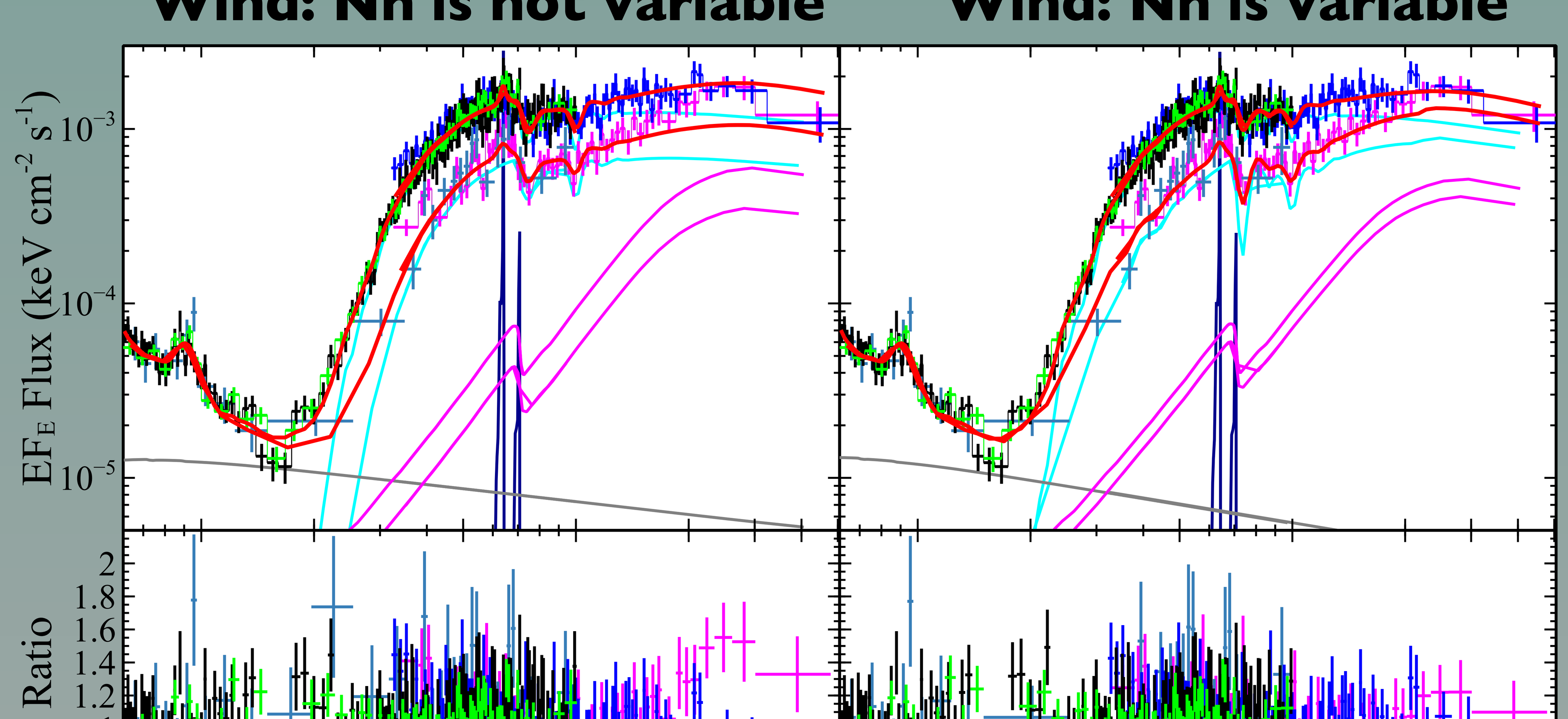

Figure 3. Best-fit MYTorus decoupled mode, applied to slice A and slice B where the left panel shows a variable neutral absorber (and constant wind), whereas the right panel shows a constant neutral absorber $N_{H,Z}$ (and variable wind). Only the latter is able to fully account for the pronounced spectral curvature seen up to 40 keV in slice B. Note that for plotting purposes we adopted the combined *NuSTAR* FPMA+FPMB spectra. As the soft X-ray model components such as MEKAL and XSTAR emissions are not variable and do not affect the MYTorus parameters, we omitted them here for clarity.

Result

the broad band spectral analysis shows that if the wind NH is held constant between the slices, the normalisation of the primary continuum has to drop in slice B to account for the lower 8-10 keV count rate, leaving an excess above 20 keV (Left Fig. 3) in the residuals. However this can be ruled out, as such a drop in the continuum is not seen in the 20–40 keV lightcurve (see Fig. 1). Instead, if the wind N_H is allowed to increase in slice B, then this can naturally account for the increase in hardness of slice B, while the overall continuum normalisation is now almost constant, consistent with the lack of variability above 20 keV as shown in Fig. 3 (right). **Thus this result suggested at high confidence level > 99.99% that the eclipsing event was not caused by a neutral absorber in the clumpy torus but instead driven by a transiting clump (or filament) in an inhomogeneous and highly ionized disc-wind located a few hundreds of Rg from the black hole**. Such rapid absorption event caused by the highly ionized disc-wind was also observed in PDS 456 (Gofford et al. 2014, ApJ, 784, 77; Matzeu et al. 2016, MNRAS, 458, 1311), which is considered to be hosting the prototype multi-phase disc-wind (Reeves et al. 2018, ApJ, 854, 8), as well as e.g., in PG 1211+143 (Pounds et al. 2003), PG 1126–041 (Giustini et al. 2011, A&A, 536, 49) and APM 08279+5255 (Chartas et al. 2002, ApJ, 579, 169).

Despite the lower X- ray luminosity that characterises MCG–03–58–007, the presence of such powerful and highly variable disc-wind resembles the one observed in the more powerful quasars with the addition that they are not usually observed in standard obscured Seyfert galaxies.