Tracking Extreme Variability in the Winds of Mrk 817 with NICER

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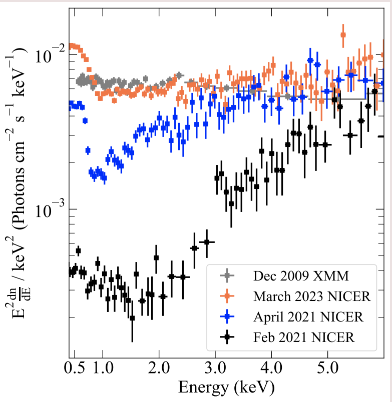
Introduction

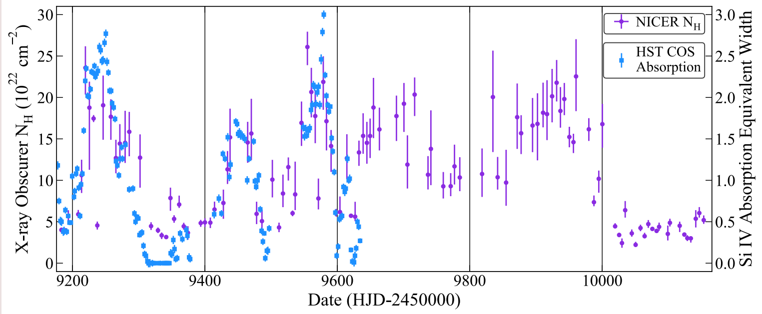
X-ray monitoring with NICER is part of a >1000-day long coordinated, multiwavelength observation program aiming to refine our picture of Active Galactic Nucleus structure.

Observations began in 2020, with Mrk 817 in a low X-ray flux state 10x fainter than historical values from 2018. We attribute this to a new partially covering, ionized obscurer [1]. The observed flux returned to historical levels in March 2023, although it is highly variable and weak obscuration remains.



Spectral shape evolution in the soft X-rays (<4 keV) is predominantly caused by changing obscuration. The hard X-rays (>4 keV) show variability in the intrinsic luminosity of the ionizing continuum, presumed to be a compact X-ray corona near the black hole. Our results are obtained from modeling individual NICER spectra with ~1ks exposures taken every other day.

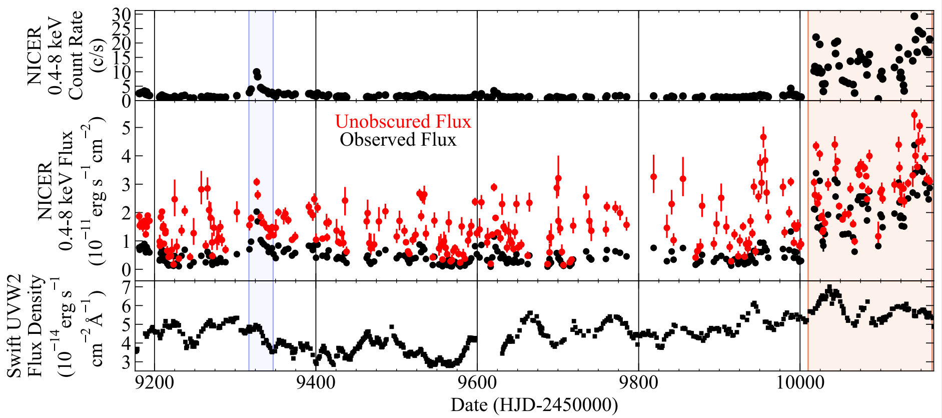
A Clumpy Outflow



The column density (N_H) of the X-ray obscurer repeatedly rises by up to 10x and returns to a baseline $N_H \approx 10^{22}$ cm^{-2} in under 100 days. Evolution in the X-ray N_H *(purple)* is strongly correlated with the equivalent widths of blueshifted UV absorption lines measured by HST COS *(blue)*, suggesting a common origin in an outflowing wind emitted from the accretion disk [2].

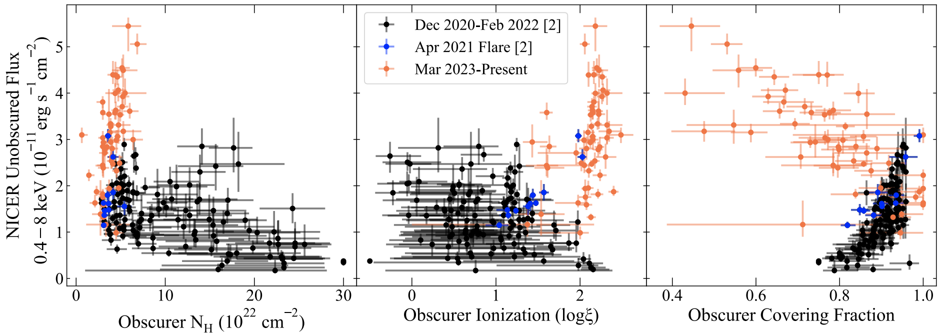
The UV obscuration disappears during the low X-ray N_H states. Since UV absorption requires much higher gas densities than X-rays do, the wind is likely a multiphase medium with a diffuse X-ray absorbing component and dense clumps. Variability in the X-ray coronal flux may create thermal instabilities in the gas as proposed by [3], causing the clumps to form.

The Obscuration Weakens



We estimate the intrinsic "unobscured" flux of the X-ray corona *(panel 2, red)* by excluding the absorption component in the spectral model. The unobscured X-rays are bright and highly variable, while the observed X-ray flux *(panel 2, black)* and count rate *(panel 1)* are mostly faint during the first two years. This stark difference is caused by a high N_H, weakly ionized obscurer.

Epochs of weak obscuration and high observed flux occurred in April 2021 *(highlighted in blue)* and from March 2023 onwards *(highlighted in orange)*. Since March 2023, the median fluxes of both the unobscured X-ray corona and the thermally-emitting accretion disk (*panel 4,* measured in the *Swift* UVW2 band, e.g. [4]) have doubled, indicating an increased mass accretion rate.



In both epochs, the N_H *(left)* of the obscuring gas is low (~10^{22} cm^{-2}) and the ionization parameter is high (*center,* $\xi = Ln^{-1}R^{-2}$, where L is the ionizing source luminosity from 1-1000 Rydberg, n is the gas density in cm^{-3}, and R is the distance to the ionizing source in cm). In April 2021, increased gas transparency is primarily driven by ionization during the X-ray flare.

The epoch in 2023 suggests that beyond a critical threshold at log(ξ) ≈ 2, changes in the X-ray source have little additional impact on ionization. This scenario has been suggested by [5] as a limiting factor on the efficiency of line-driven acceleration in winds. The X-rays appear to disrupt the wind even at this maximum ionization, as the covering fraction of the gas *(right)* has dropped by 60% and has become anticorrelated with the unobscured X-ray flux (R=0.7).

Individual NICER observations show X-ray obscuration consistent with a **clumpy, ionized wind** launched from the inner accretion disk of the supermassive black hole.

As the intrinsic **X-ray flux increases**, the wind reaches a **maximum level of ionization and disperses**, covering less of the source.

Geometry of the Disk Wind

The obscuring wind is placed by UV absorption line models at ~3 light days from the black hole [1]. Combined with measurements of time-delayed variability in other parts of the AGN using a technique known as "reverberation mapping," the wind is estimated to originate from the accretion disk and lie interior to the relativistically moving gas of the broad line region (BLR) [6],[7]. Outflowing wind speeds of ~5,000 km s^{-1} are measured from blueshifted X-ray absorption lines in XMM spectra [8].

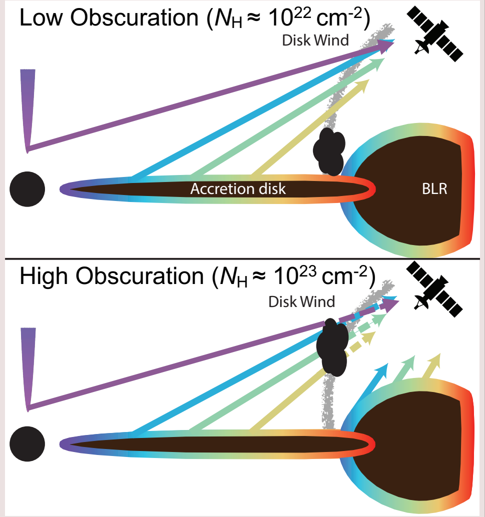


Figure adapted from [7].

The high-N_H sections of the wind observed by NICER likely form near the accretion disk, disrupting reverberation signals in the UV/optical/infrared, and are then launched outwards across our line-of-sight. Increases in the ionization parameter associated with a bright X-ray corona indicate that the wind is at least partially accelerated by line-driven heating.

[1] Kara, E. et al. 2021, ApJ, 922, 151
[2] Partington, E. R. et al. 2023, ApJ, 947, 2
[3] Waters, T. et al. 2022, ApJ, 931, 134
[4] Cackett, E.M., accepted to ApJ
[5] Higginbottom, N. et al. 2014, ApJ, 789, 19
[6] Homayouni, Y. et al., submitted to ApJ
[7] Lewin, C. et al. in prep.
[8] Zaidouni, F. et al. in prep.