Evolution of an ionized obscurer in Mrk 817

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Campaign Overview

- Second AGN STORM Campaign, following study of NGC 5548 (De Rosa et al., 2015)
  - A year-long multiwavelength, coordinated reverberation mapping campaign using HST, Swift, NICER, XMM, Chandra and ground-based photometry & spectroscopy
  - Discussion of optical/NIR observations and reverberation mapping results in ApJ paper

Mrk 817 Selection Characteristics

- Historically unobscured source, no broad UV absorption lines prior to campaign
- Low galactic foreground extinction \((E(B - V) \approx 0.02\text{mag})\)
- Similar mass to NGC 5548 \((Mrk\ 817\ M_{BH} \approx 3.85 \times 10^7 \ M_{\odot})\), with higher Eddington ratio \((L/L_{Edd} \sim 0.2\) for Mrk 817, and \(L/L_{Edd} \sim 0.03\) for NGC 5548)
Figure 1: An overview of AGN STORM 2 campaign Mrk 817, segmented by emission wavelength (Kara, submitted to ApJ).

- Ionized obscurer at the inner broad line region (BLR) explains new X-ray and UV absorption features
- Cloudy photoionization modeling (Ferland et al., 2017) places UV absorber at a $R \sim 3$ light days, near inner BLR
Coordinated X-ray/UV Observations

- Daily *Swift* XRT and UVOT observations began 2020-11-22, with average exposure ~1ks
- *HST* Cosmic Origins Spectrograph (COS) observations taken with two-day cadence, beginning 2020-11-24
- NICER monitoring with two-day cadence began 2020-11-28, binned into epochs of ~10 days (~5-10 ks per epoch) for spectral modeling
- Following detection of low X-ray flux state, 135 ks observation with XMM-Newton RGS conducted on 2020-12-18

A separate study by Miller et al. (2021) adds 134.7 ks NuSTAR observation on 2020-12-18 with contemporaneous 2.12 ks *Swift* XRT observation (arXiv: 2103.09789)
Figure 2: Cosmic Origins Spectrograph (COS) Far-UV spectrum of Mrk 817, taken 12-28-2020 (blue) and 2009-2010 (grey). **New broad absorption features detected in 2020 are shown in blue** (Kara, submitted to ApJ).

- Model uses power law continuum, with broad and narrow gaussian components for absorption and emission lines.
GTI Filtering and Background Subtraction

- Data were processed using NICERDAS tools from HEAsoft v6.28 and CALDB version xti20200722 with the energy scale (gain) version “optmv10”

- Many GTIs contain background flares (~100 s) at 13-15 keV which dominate 0.3-10 keV count rate
  - Periods with 13-15 keV count rate > 0.12 c/s were excluded from GTIs

- 3C50 used for background modeling

- One observation was excluded following the filtering process in Remillard et al. (submitted).

Figure 3: Cleaned light curves for obsid 3201860129, filtered with nicerl2
Overshoot Rate Filtering

- ~15 day period at low elevation angle (32° < ELV < 50°) where bg-subtracted Swift and NICER count rates diverge (grey box)
- Cleaned light curve excludes particle dominated observations with mean overshoot rate > 0.28 c/s
- Source brightness drops by factor of 3 since beginning of the campaign

Figure 4: Background-subtracted count rates from Swift (grey), and NICER (purple). Mean overshoot rate for each NICER observation is shown in red, with a cutoff of 0.28.
Figure 5: X-ray counts multiplied by an $E^2$ power law, showing a significant drop in soft X-ray counts between 2009 (grey) and 2020 (purple) and clear evolution during our monitoring (Kara, submitted to ApJ).
Ionized obscurer model with XMM-Newton

- Power law ($E_{\text{cut}} = 300$ keV) absorbed by partial covering ionized absorber (dot-dashed lines)
- Photoionization from two circumnuclear gas regions (PION, dashed lines)
- Relativistic reflection (RellxilD, dotted lines)
- Spectral model consistent with Miller et al. (2021)

Alternate Model: Intrinsically low-flux corona

- Poor joint XMM-NuSTAR fit, NuSTAR flux overpredicted
- Ionized obscurer provides a better fit to NICER data at each epoch

Figure 6: Joint XMM-Newton/ archival NuSTAR spectrum fit to ionized obscurer model (Kara, submitted to ApJ).
Applying XMM-Newton model to NICER data

- NICER spectra are binned into 10-day epochs, combined using `addspec`, and fit in XSPEC v12.11.1
- Elemental abundances, black hole spin, emission from parsec-scale gas are frozen
- Column density, ionization parameter, covering fraction, continuum power law index, and normalization are allowed to vary
- Column density demonstrates significant variability, and scales directly with equivalent width of broad UV absorption troughs

Figure 7: (Top) NICER 0.3-10 keV X-ray flux [erg cm\(^{-2}\) s\(^{-1}\)] (purple) and HST 1180 Å flux [erg cm\(^{-2}\) s\(^{-1}\) Å\(^{-1}\)] (blue) (Bottom) X-ray obscurer column density [10\(^{22}\) cm\(^{-2}\)] (purple) and broad PV absorption trough equivalent width [Å] (blue) (Kara, submitted to ApJ).
Summary

Modeling of Ionized Obscurer

- ~3x decrease in X-ray brightness attributed to ~10x increase in $N_H$ of partial covering ionized obscurer, with no significant change in covering fraction
  - Evolution of X-ray $N_H$ only possible with NICER - Swift sees changes in hardness, but not a large enough signal to do robust spectral modeling.
- Evolution of $N_H$ with NICER matches evolution of UV broad absorption lines with HST COS

New filtering methods for low count-rate NICER observations

- Low count rate sources like Mrk 817 (1-3 c/s) are susceptible to background modeling challenges caused by high particle background activity
- Two additive remedies are introduced:
  - Excluding short (~100s) flares by filtering out times with high 13-15 keV count rates prior to background modeling (>0.12 c/s for Mrk 817)
  - Rejecting observations with high overshoot rates, indicative of domination by particle background throughout the observation (>0.28 c/s for Mrk 817)
Figure 7: Recovering brightness of Mrk 817 in second observing phase, as seen by Swift XRT (grey) and NICER (purple)