Evolution of an ionized obscurer in Mrk 817

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In Collaboration with AGN STORM 2 Team (arXiv: 2105.05840)

Introduction

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
- First results for Mrk 817 written by Erin Kara, submitted to ApJ (arXiv: 2105.05840)
  - 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 ($E(B - V) \approx 0.02$mag)
- Similar mass to NGC 5548 (Mrk 817 $M_{BH} \approx 3.85\times10^7\ M_\odot$), with higher Eddington ratio ($L/L_{Edd} \sim 0.2$ for Mrk 817, and $L/L_{Edd} \sim 0.03$ for NGC 5548)

Introduction

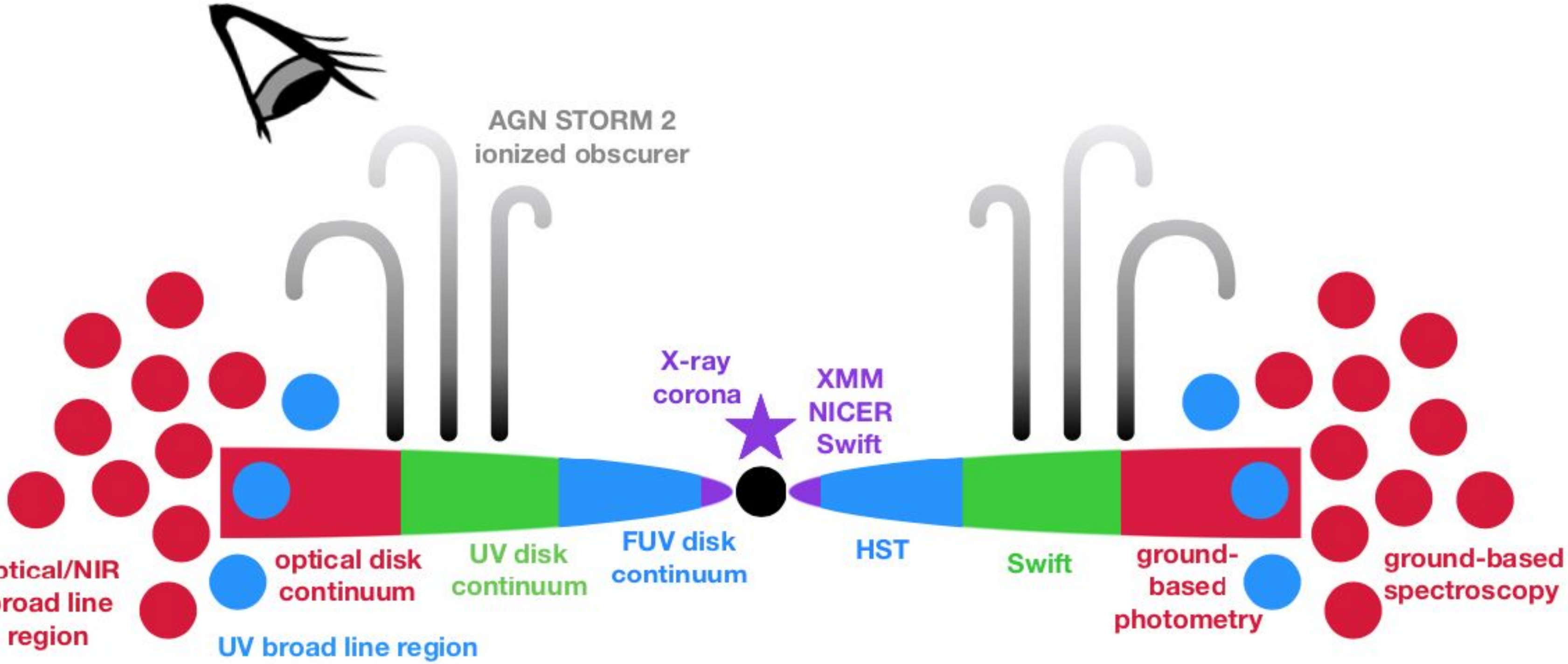

Figure 1: An overview of AGN STORM 2 campaign Mrk 817, segmented by emission wavelength (Kara, submitted to ApJ).

- 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 ~ 3 light days, near inner BLR

Introduction

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)

UV Observations with *HST*

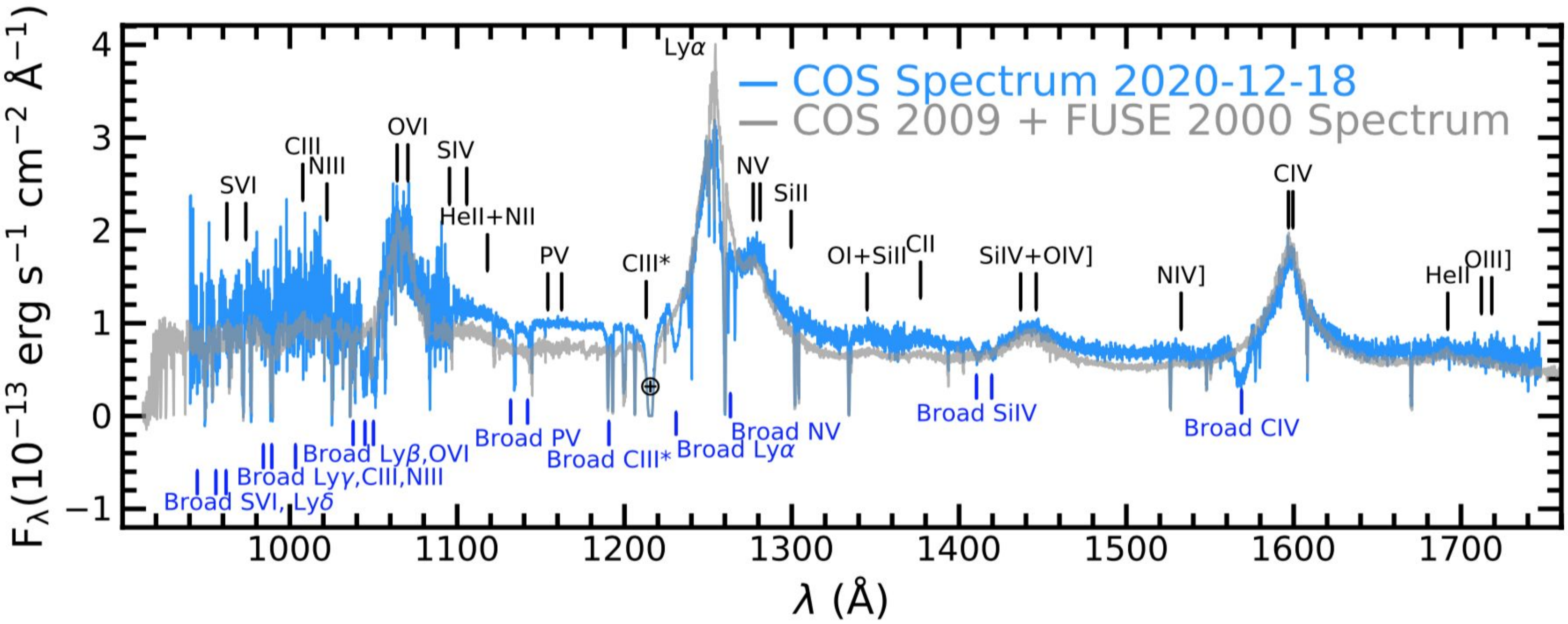

Figure 2: Cosmic Origins Spectrograph (COS) Far-UV spectrum of Mrk 817, taken 12-28-2020 (blue) and 2009-2010 (grey). **New broad absorption features detected in 2020 are shown in blue** (Kara, submitted to ApJ).

- Model uses power law continuum, with broad and narrow gaussian components for absorption and emission lines

NICER Data Reduction

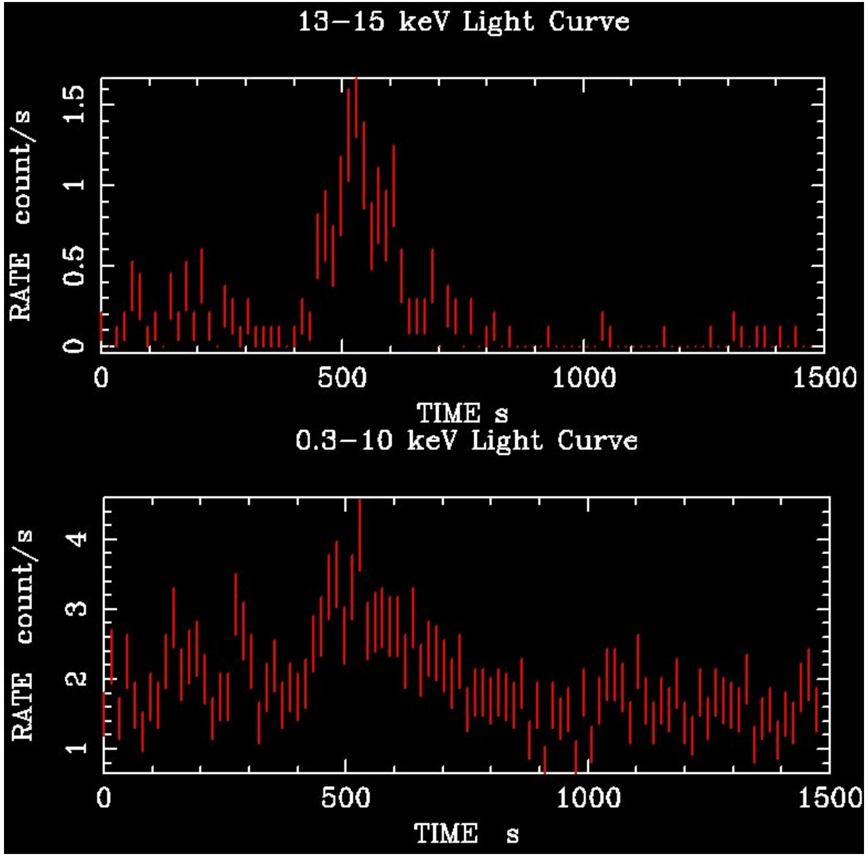

Figure 3: Cleaned light curves for obsid 3201860129, filtered with nicerl2

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).

NICER Data Reduction

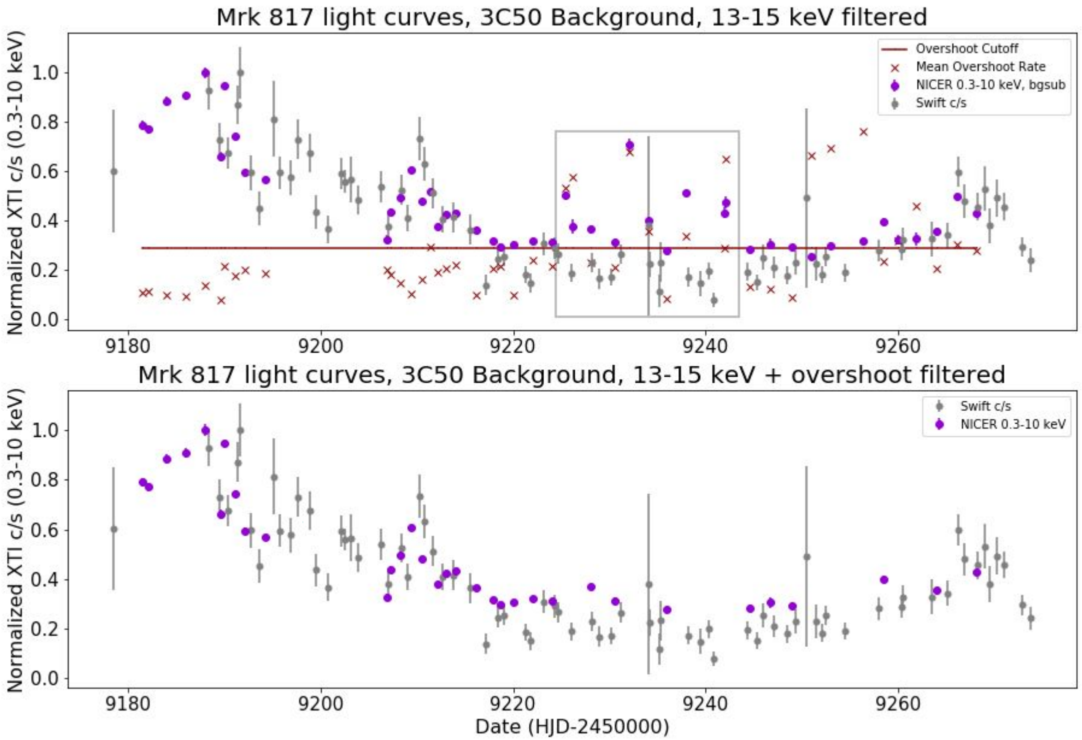

Figure 4: Background-subtracted count rates from *Swift* (grey), and NICER (purple). Mean overshoot rate for each NICER observation is shown in red, with a cutoff of 0.28.

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

X-ray Spectral Evolution

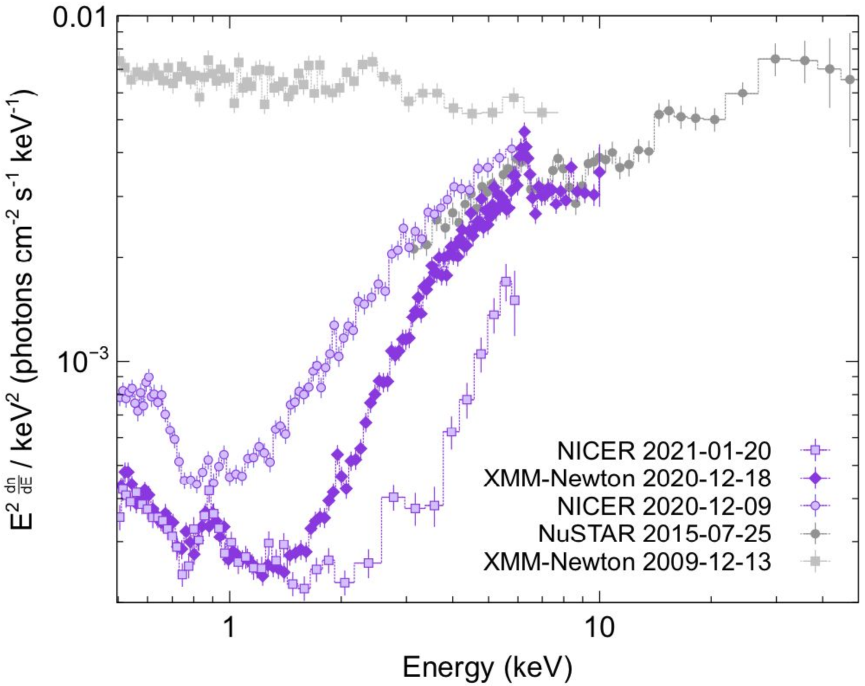

Figure 5: X-ray counts multiplied by an E^2 power law, showing a significant drop in soft X-ray counts between 2009 (grey) and 2020 (purple) and clear evolution during our monitoring (Kara, submitted to ApJ).

X-ray Spectral Evolution

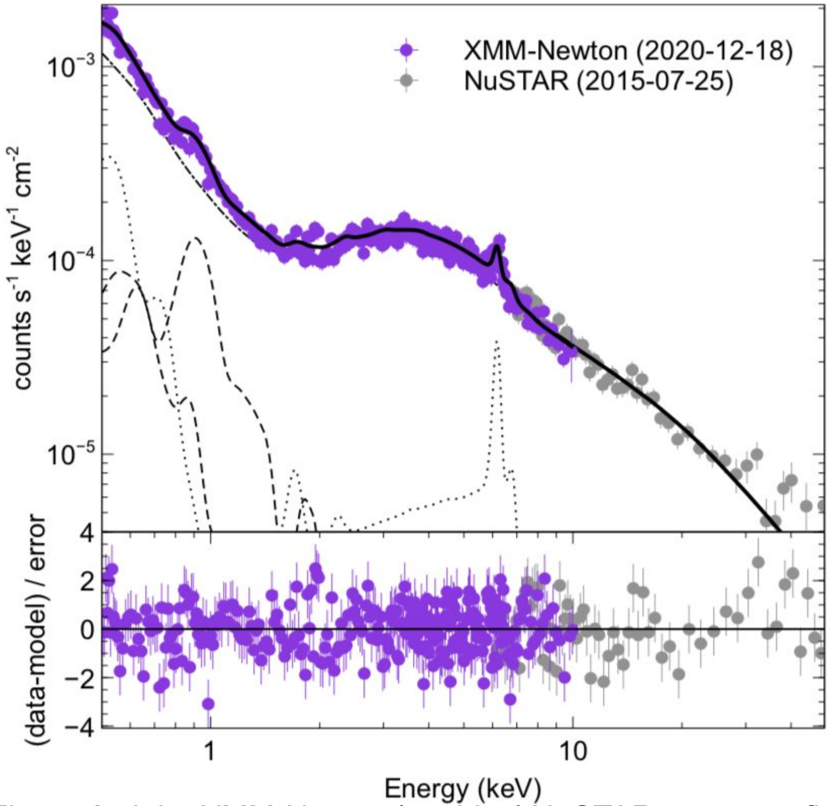

Figure 6: Joint XMM-Newton/ archival NuSTAR spectrum fit to ionized obscurer model (Kara, submitted to ApJ).

Ionized obscurer model with XMM-Newton

- Power law (E_{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

X-ray Spectral Evolution

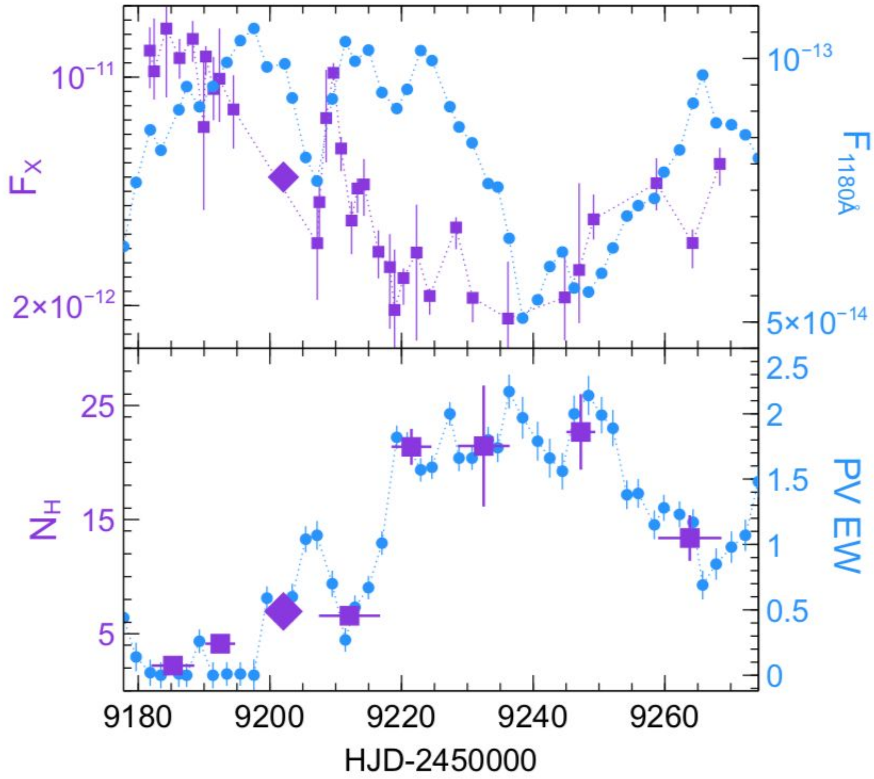

Figure 7: (Top) NICER 0.3-10 keV X-ray flux [erg cm^{-2} s^{-1}] (purple) and HST 1180 Å flux [erg cm^{-2} s^{-1} Å^{-1}] (blue) (Bottom) X-ray obscurer column density [10^{22} cm^{-2}] (purple) and broad PV absorption trough equivalent width [Å] (blue) (Kara, submitted to ApJ).

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**

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)

Updated look at Mrk 817

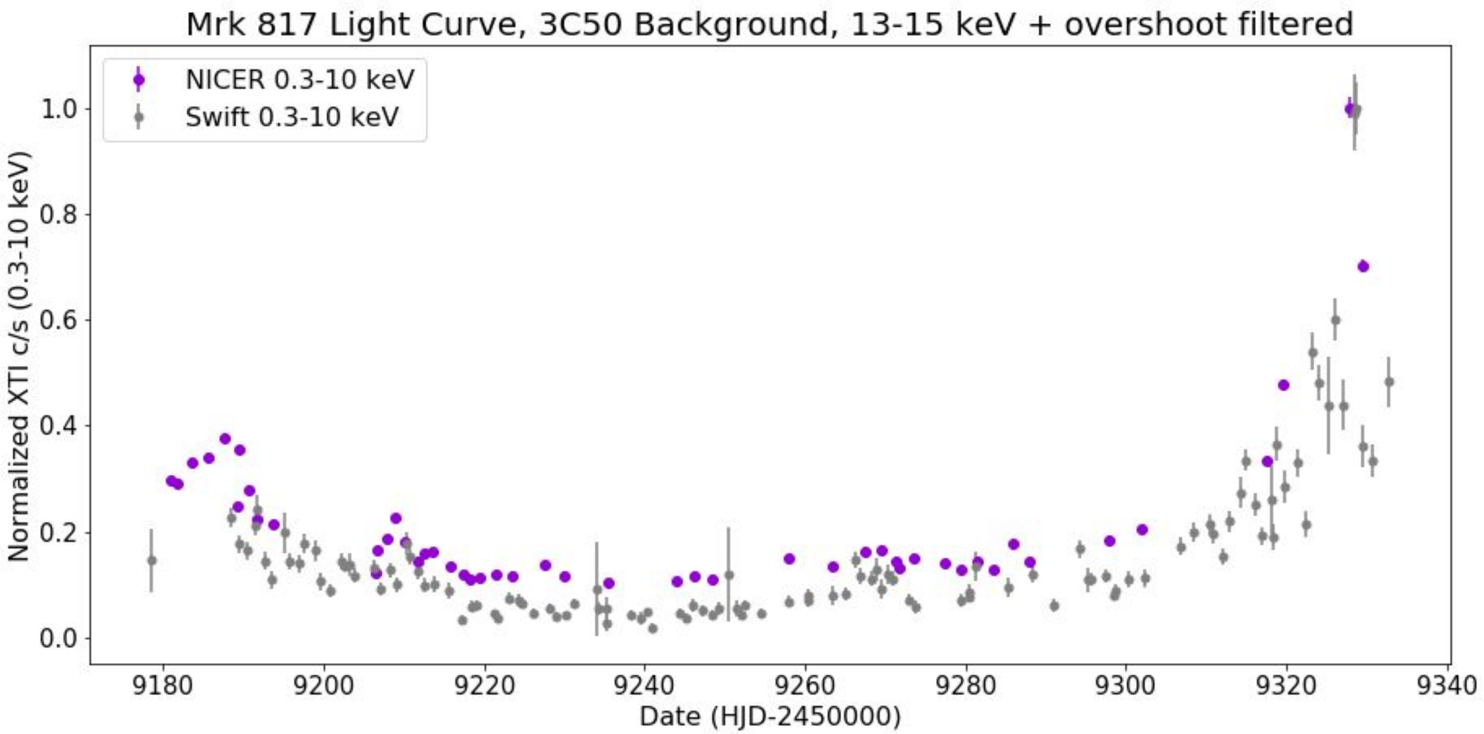

Figure 7: Recovering brightness of Mrk 817 in second observing phase, as seen by *Swift* XRT (grey) and NICER (purple)