LONG-TIMESCALE X-RAY VARIABILITY OF BAL AND MINI-BAL QUASARS: CATALOG PRODUCTION

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Here we describe in more detail the methods used to select BAL and mini-BAL quasars from the Sloan Digital Sky Survey (SDSS; York et al. 2000) Data Release 16 quasar catalog (DR16Q; Lyke et al. 2020) as well as the X-ray data processing and source-extraction methods.

We compiled our list of BAL quasars from the DR16Q catalog. This catalog combined all of the spectroscopically confirmed quasars from previous SDSS data releases with new observations to generate a large catalog of 740,414 bona fide quasars. Included in this catalog is a measurement of the balnicity index (BI; Weymann et al. 1991) and the absorption index (AI; Hall et al. 2002) which are common measures of the strength of the absorption trough near the C IV emission line. There is no canonical definition separating BAL and mini-BAL quasars in terms of their absorption strength; therefore, we adopt the definition in Gibson et al. (2009) where BAL quasars have BI > 0 and mini-BAL quasars have BI = 0 and AI > 0. Imposing these restrictions, along with a brightness cutoff at $i < 20$, we find a total of 37,207 BAL and mini-BAL quasars. Finally, we searched for counterparts in *Chandra* observations that were observed multiple times using a similar approach to that outlined in Section 2 of Timlin et al. (2020b), where we restrict the observations to be longer than 5 ks and the quasar to lie less than nine arcmin from the *Chandra* aim-point. We found 293 observations (251 of which were serendipitous, indicating that our sample is not biased substantially by targeted observations) of 93 BAL and mini-BAL quasars lie within the *Chandra* footprint that have multiple sensitive observations.

All 293 observations were processed in the same manner as in Timlin et al. (2020b) using CIAO tools (Fruscione et al. 2006). After reprocessing and deflaring, sources were extracted using `wavdetect` in soft (0.5–2 keV), hard (2–7 keV), and full (0.5–7 keV) bands. If the X-ray positions from source extraction matched within 2'' of the optically determined position, the X-ray position was used, otherwise the positions in the DR16 quasar catalog were adopted. Counts were extracted following the method in Section 2 of Timlin et al. (2020a) by centering circular regions on the adopted source position. The radius of these circles increased as the off-axis angle of the source on the detector increased. Background counts were also extracted using circular annuli surrounding the source position. In cases where the background region overlapped with a chip boundary, ‘pie’-shaped regions were adopted (e.g., Pu et al. 2020). Background regions were visually inspected to ensure that no sources were present in the background aperture. Finally, exposure maps were created using the `flux_image` tool as in Timlin et al. (2020b) to quantify the loss of effective exposure for sources at large off-axis angles as well as the degradation of the ACIS quantum efficiency with time and have units of photons^{−1} cm² s. These exposure maps were created in the soft, hard, and full energy bands (with effective energies of 1, 3, and 2 keV, respectively), and were used to compute the effective exposure times in each band.

As in Timlin et al. (2020b), we computed the count flux (cts cm^{−2} s^{−1}) instead of physical flux (erg cm^{−2} s^{−1}) for each observation to mitigate additional uncertainty in the flux that comes from fitting a spectral model (see Section 4.1 of Timlin et al. 2020b for more details). The count fluxes were computed in the observed-frame full band (0.5–7 keV). The BAL quasars in this sample span a moderate range in redshift ($z = 1.57$ – 3.2) and thus the observed-frame bandpass used in this investigation to compute the count fluxes spans similar rest-frame energies for all the quasars in the sample. Variability amplitudes are computed between every epoch of observation by taking the ratio of the earlier observation to the later observation. Therefore, for each X-ray light curve with N epochs, there are $N(N-1)/2$ unique permutations of variability amplitudes. To ensure that any single quasar does not dominate the sample due to its large number of epochs, we downsampled the X-ray light curves to only 3 observations: the first epoch in the light

curve, the last epoch in the light curve, and a randomly drawn epoch between the two (see [Timlin et al. 2020b](#) for more details). For the final sample discussed in the research note, we also remove quasars that are radio loud, where the radio-loudness parameter, R , is defined in the same way as in Section 3.2 of [Timlin et al. \(2020b\)](#). Radio-loud quasars are included and flagged in the catalog presented below.

This catalog contains all 293 observation where each row represents a single observation. The columns presented in the Table are outlined below. Unique quasars can be distinguished through the NAME column, and radio-loud quasars can be removed using the RL_FLAG. See [Timlin et al. \(2020b\)](#) for more information about the columns.

- Column (1): SDSS name
- Column (2): J2000 RA
- Column (3): J2000 DEC
- Column (4): Redshift (DR16Q)
- Column (5): log Galactic column density (cm^{-2} ; [Kalberla et al. 2005](#))
- Column (6): Observation ID
- Column (7): Off-axis Angle (arcmin)
- Column (8): Effective exposure time (seconds)
- Column (9): Detection probability in the soft band
- Column (10): Detection probability in the hard band
- Column (11): Detection probability in the full band
- Column (12): Raw counts (soft band)
- Column (13): Raw background counts (soft band)
- Column (14): Net counts (soft band)
- Column (15): 1σ upper limit on net counts (soft band)
- Column (16): 1σ lower limit on net counts (soft band)
- Column (17): Raw counts (hard band)
- Column (18): Raw background counts (hard band)
- Column (19): Net counts (hard band)
- Column (20): 1σ upper limit on net counts (hard band)
- Column (21): 1σ lower limit on net counts (hard band)
- Column (22): Raw counts (full band)
- Column (23): Raw background counts (full band)
- Column (24): Net counts (full band)
- Column (25): 1σ upper limit on net counts (full band)
- Column (26): 1σ lower limit on net counts (full band)
- Column (27): Mean soft-band exposure map pixel value of the source region ($\text{photons}^{-1} \text{ cm}^2 \text{ s}$)
- Column (28): Mean soft-band exposure map pixel value of the background region ($\text{photons}^{-1} \text{ cm}^2 \text{ s}$)

- Column (29): Mean hard-band exposure map pixel value of the source region ($\text{photons}^{-1} \text{ cm}^2 \text{ s}$)
- Column (30): Mean hard-band exposure map pixel value of the background region ($\text{photons}^{-1} \text{ cm}^2 \text{ s}$)
- Column (31): Mean full-band exposure map pixel value of the source region ($\text{photons}^{-1} \text{ cm}^2 \text{ s}$)
- Column (32): Mean full-band exposure map pixel value of the background region ($\text{photons}^{-1} \text{ cm}^2 \text{ s}$)
- Column (33): Chip-edge flag (0 = good detection; 1 = edge detection).
- Column (34): *Chandra* start time (seconds)
- Column (35): SDSS Plate ID
- Column (36): SDSS MJD
- Column (37): SDSS FIBER ID
- Column (38): DR16Q BAL probability
- Column (39): C IV balnicity index
- Column (40): Uncertainty in the balnicity index
- Column (41): Absorption index
- Column (42): Uncertainty in the absorption index
- Column (43): BAL flag (1=BAL)
- Column (44): miniBAL flag (1=miniBAL)
- Column (45): Observed *i*-band magnitude
- Column (46): Uncertainty on the *i*-band magnitude
- Column (47): *i*-band extinction
- Column (48): Absolute *i*-band magnitude (corrected to $z = 2$)
- Column (49): $\log 2500 \text{ \AA}$ monochromatic luminosity ($\text{erg s}^{-1} \text{ Hz}^{-1}$)
- Column (50): $\log 2500 \text{ \AA}$ flux density ($\text{erg cm}^{-2} \text{ s}^{-1} \text{ Hz}^{-1}$)
- Column (51): 2 keV flux density (erg s^{-1})
- Column (52): 1σ lower limit on the 2 keV flux density ($\text{erg cm}^{-2} \text{ s}^{-1} \text{ Hz}^{-1}$)
- Column (53): 1σ upper limit on the 2 keV flux density ($\text{erg cm}^{-2} \text{ s}^{-1} \text{ Hz}^{-1}$)
- Column (54): α_{ox} determined using the 2 keV flux density derived from the soft-band
- Column (55): α_{ox} determined using the 2 keV flux density derived from the full-band
- Column (56): Targeted observation (1=targeted)
- Column (57): Radio-loudness flag (1=radio loud, defined as $R > 30$; see [Timlin et al. 2020b](#))

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