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J/ApJ/836/99 NuSTAR serendipitous survey: the 40-month catalog (Lansbury+, 2017)

The NuSTAR serendipitous survey: the 40-month catalog and the properties of the distant high-energy X-ray source population.

Lansbury G.B., Stern D., Aird J., Alexander D.M., Fuentes C., Harrison F.A., Treister E., Bauer F.E., Tomsick J.A., Balokovic M., Del Moro A., Gandhi P., Ajello M., Annuar A., Ballantyne D.R., Boggs S.E., Brandt W.N., Brightman M., Chen C.-T.J., Christensen F.E., Civano F., Comastri A., Craig W.W., Forster K., Grefenstette B.W., Hailey C.J., Hickox R.C., Jiang B., Jun H.D., Koss M., Marchesi S., Melo A.D., Mullaney J.R., Noirod G., Schulze S., Walton D.J., Zappacosta L., Zhang W.W.

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Mission_Name: NuSTAR

Keywords: catalogs; galaxies: active; galaxies: nuclei; quasars: general; surveys; X-rays: general

Abstract:

We present the first full catalog and science results for the Nuclear Spectroscopic Telescope Array (NuSTAR) serendipitous survey. The catalog incorporates data taken during the first 40 months of NuSTAR operation, which provide ~20Ms of effective exposure time over 331 fields, with an areal coverage of 13deg², and 497 sources detected in total over the 3-24keV energy range. There are 276 sources with spectroscopic redshifts and classifications, largely resulting from our extensive campaign of ground-based spectroscopic follow-up. We characterize the overall sample in terms of the X-ray, optical, and infrared source properties. The sample is primarily composed of active galactic nuclei (AGNs), detected over a large range in redshift from $z=0.002$ to 3.4 (median of $z \geq 0.56$), but also includes 16 spectroscopically confirmed Galactic sources. There is a large range in X-ray flux, from $\log(f_{3-24\text{keV}}/\text{erg/s/cm}^2) \sim -14$ to -11 , and in rest-frame 10-40keV luminosity, from $\log(L_{10-40\text{keV}}/\text{erg/s}) \sim 39$ to 46, with a median of 44.1. Approximately 79% of the NuSTAR sources have lower-energy (<10keV) X-ray counterparts from XMM-Newton, Chandra, and Swift XRT. The mid-infrared (MIR) analysis, using WISE all-sky survey data, shows that MIR AGN color selections miss a large fraction of the NuSTAR-selected AGN population, from ~15% at the highest luminosities ($L_X > 10^{44}$ erg/s) to ~80% at the lowest luminosities ($L_X < 10^{43}$ erg/s). Our optical spectroscopic analysis finds that the observed fraction of optically obscured AGNs (i.e., the type 2 fraction) is $F_{\text{Type2}} = 53_{-15}^{+14}\%$, for a well-defined subset of the 8-24keV selected sample. This is higher, albeit at a low significance level, than the type 2 fraction measured for redshift- and luminosity-matched AGNs selected by <10keV X-ray missions.

Description:

Over the period from 2012 July to 2015 November, which is the focus of the current study, there are 510 individual NuSTAR exposures that have been incorporated into the serendipitous survey. These exposures were performed over 331 unique fields (i.e., 331 individual sky regions, each with contiguous coverage composed of one or more NuSTAR exposures), yielding a total sky area coverage of 13deg². Table 1 lists the fields chronologically. The fields have a cumulative exposure time of 20.4Ms.

We have undertaken a campaign of dedicated spectroscopic follow-up in the optical-IR bands, obtaining spectroscopic identifications for a large fraction (56%) of the total sample. Since NuSTAR performs science pointings across the whole sky, a successful ground-based follow-up campaign requires the use of observatories at a range of geographic latitudes, and preferably across a range of dates throughout the sidereal year. This has been achieved through observing programs with, primarily, the following telescopes over a multiyear period (2012 Oct 10 to 2016 Jul 10): the Hale Telescope at Palomar Observatory (5.1m; PIs F. A. Harrison and D. Stern); Keck I and II at the W. M. Keck Observatory (10m; PIs F. A. Harrison and D. Stern); the New Technology Telescope (NTT) at La Silla Observatory (3.6m; PI G. B. Lansbury); the Magellan I (Baade) and Magellan II (Clay) Telescopes at Las Campanas Observatory (6.5m; PIs E. Treister and F. E. Bauer); and the Gemini-South observatory (8.1m; PI E. Treister).

File Summary:

FileName	Lrecl	Records	Explanations
ReadMe	80	.	This file
table1.dat	82	591	Details of the individual NuSTAR observations which

			make up the serendipitous survey
table5.dat	903	498	The primary NuSTAR serendipitous source catalog
table6.dat	234	303	Summary of the optical spectroscopy for the NuSTAR serendipitous survey sources
table7.dat	377	64	The secondary NuSTAR serendipitous source catalog
table8.dat	234	46	Summary of the optical spectroscopy for the secondary catalog sources

See also:

[IX/15](#) : Einstein EMSS Survey (Gioia+ 1990, Stocke+ 1991)
[I/284](#) : The USNO-B1.0 Catalog (Monet+ 2003)
[VII/259](#) : 6dF galaxy survey final redshift release (Jones+, 2009)
[II/311](#) : WISE All-Sky Data Release (Cutri+ 2012)
[IX/45](#) : The Chandra Source Catalog, Release 1.1 (Evans+ 2012)
[II/319](#) : UKIDSS-DR9 LAS, GCS and DXS Surveys (Lawrence+ 2012)
[IX/50](#) : XMM-Newton Serendipitous Source Catalogue 3XMM-DR6 (XMM-SSC, 2016)
[J/A+AS/97/483](#) : Optical spectroscopy of 1Jy, S4 and S5 sources (Stickel+ 1993)
[J/ApJ/518/656](#) : ASCA Large Sky Survey (Ueda+, 1999)
[J/MNRAS/327/771](#) : BeppoSAX HELLAS survey. II. (Fiore+, 2001)
[J/ApJ/554/742](#) : Chandra Deep Survey of the HDF-N (Hornschemeier+, 2001)
[J/A+A/371/833](#) : ROSAT Ultra Deep Survey (Lehmann+, 2001)
[J/AJ/126/539](#) : The Chandra Deep Fields North and South (Alexander+, 2003)
[J/AJ/126/632](#) : UBVRIZ'HK' photometry of 2Ms CDFN X-ray sources (Barger+, 2003)
[J/A+A/409/79](#) : HELLAS2XMM survey. IV. (Fiore+, 2003)
[J/ApJ/596/944](#) : SEXSI catalog (Harrison+, 2003)
[J/MNRAS/342/802](#) : Chandra survey of 13-h XMM/ROSAT survey (McHardy+, 2003)
[J/ApJ/582/615](#) : SHEEP survey (Nandra+, 2003)
[J/ApJS/150/19](#) : ChaMP. I. First X-ray source catalog (Kim+, 2004)
[J/A+A/418/465](#) : Mid-infrared and hard X-ray emission in AGN (Lutz+, 2004)
[J/ApJS/161/21](#) : Extended Chandra Deep Field-South survey (Lehmer+, 2005)
[J/MNRAS/356/568](#) : Deep Chandra survey of the Groth Strip (Nandra+, 2005)
[J/ApJS/161/185](#) : GIS catalog project : source catalog II (Ueda+, 2005)
[J/ApJS/165/19](#) : SEXSI catalog. III (Eckart+, 2006)
[J/A+A/448/L9](#) : Position catalogue of Swift XRT afterglows (Moretti+, 2006)
[J/ApJS/166/128](#) : Narrow line Seyfert 1 galaxies from SDSS-DR3 (Zhou+, 2006)
[J/A+A/476/1191](#) : XMM-Newton serendipitous survey. IV (Barcons+, 2007)
[J/A+A/475/775](#) : INTEGRAL all-sky survey of hard X-ray sources (Krivonos+, 2007)
[J/ApJ/678/102](#) : BAT X-ray survey. I. (Ajello+, 2008)
[J/ApJ/681/113](#) : Swift BAT survey of AGNs (Tueller+, 2008)
[J/ApJS/180/102](#) : AEGIS-X: Chandra deep survey (Laird+, 2009)
[J/A+A/495/691](#) : Multifrequency catalog of blazars, Roma-BZCAT (Massaro+, 2009)
[J/A+A/493/339](#) : XMM-Newton serendipitous Survey. V. (Watson+, 2009)
[J/ApJ/713/970](#) : Low-resolution SED templates for AGNs & galaxies (Assef+, 2010)
[J/ApJ/708/584](#) : SEXSI Spitzer catalog (Eckart+, 2010)
[J/ApJ/728/58](#) : Swift-BAT survey of AGNs (Burlon+, 2011)
[J/ApJS/195/10](#) : The CDF-S survey: 4Ms source catalogs (Xue+, 2011)
[J/ApJS/201/34](#) : Swift-INTEGRAL X-ray (SIX) survey (Bottacini+, 2012)
[J/ApJ/754/45](#) : IR properties of Swift/BAT X-ray AGNs (Ichikawa+, 2012)
[J/MNRAS/426/1750](#) : INTEGRAL/IBIS AGN catalogue (Malizia+, 2012)
[J/ApJ/753/104](#) : AGN identifications from AKARI and Swift (Matsuta+, 2012)
[J/ApJ/758/129](#) : 4Ms Chandra Deep Field South 6-8keV galaxies (Xue+, 2012)
[J/ApJ/772/26](#) : AGN with WISE. II. The NDWFS Bootes field (Assef+, 2013)
[J/ApJS/207/19](#) : Hard X-ray survey from Swift-BAT 2004-2010 (Baumgartner+, 2013)
[J/ApJ/779/104](#) : Luminous dust-poor SDSS QSOs at $z < 4.5$ (Jun+, 2013)
[J/ApJ/765/L26](#) : Swift/BAT ultra-hard X-ray data from GOALS LIRGs (Koss+, 2013)
[J/ApJ/763/111](#) : X-ray spectral analysis of Swift/BAT AGNs (Vasudevan+, 2013)
[J/ApJ/808/185](#) : NuSTAR surveys: COSMOS catalog (Civano+, 2015)
[J/ApJ/808/184](#) : NuSTAR surveys: ECDF-S catalog (Mullaney+, 2015)
[J/ApJ/815/L13](#) : Compton-thick AGNs from 70-month Swift/BAT obs. (Ricci+, 2015)
[J/ApJ/807/129](#) : X-ray to MIR luminosities relation of AGNs (Stern, 2015)

Byte-by-byte Description of file: [table1.dat](#)

Bytes	Format	Units	Label	Explanations
1- 4	A4	---	Field	Field identifier (1)
6- 28	A23	---	Target	Primary science target identifier
30- 31	I2	---	NObs	[1/15]? Number of individual exposures in Field
33- 43	I11	---	ObsID	? Observation identifier
45- 54	A10	"Y/M/D"	Date	? Field observation start UT date
56- 61	F6.2	deg	RAdeg	? Aim point Right Ascension (J2000)
63- 68	F6.2	deg	DEdeg	? Aim point Declination (J2000)
70- 75	F6.1	ks	Exp	[1.8/1104] Exposure time (2)
77- 78	I2	---	N	[0/12]? Number of serendipitous sources detected
80	I1	---	A15	[0/1]? Aird+ 2015ApJ...815...66A flag (3)
82	I1	---	H16	[0/1]? Harrison+ 2016ApJ...831..185H flag (3)

Note (1): For fields with multiple NuSTAR exposures (i.e., Nobs>1), each individual component exposure is listed with a letter suffixed to the field ID (e.g., 3a and 3b).

Note (2): For a single focal plane module (i.e., averaged over FPMA and FPMB).

Note (3): Binary flags to highlight the serendipitous survey fields used for the Aird+ [2015ApJ...815...66A](#) and Harrison+ [2016ApJ...831..185H](#) studies.

Byte-by-byte Description of file: [table5.dat](#)

Bytes	Format	Units	Label	Explanations
1-	3	I3	---	Seq [1/498] Running sequence number
5-	10	A6	---	[NuSTAR]
11-	24	A14	---	NuSTAR Unique NuSTAR source name (JHHMMSS+DDMM.m)
26-	35	F10.6	deg	RAdeg Right Ascension in decimal degrees (J2000)
37-	46	F10.6	deg	DEdeg Declination in decimal degrees (J2000)
48	I1	---	SF1	[0/1] Soft (3-8keV) band detection flag (1) .
50	I1	---	HF1	[0/1] Hard (8-24keV) band detection flag (1) .
52	I1	---	FF1	[0/1] Full (3-24keV) band detection flag (1) .
54	I1	---	Sdbf1	[0/1] Deblended soft band detection flag (2) .
56	I1	---	Hdbf1	[0/1] Deblended hard band detection flag (2) .
58	I1	---	Fdbf1	[0/1] Deblended full band detection flag (2) .
60-	67	F8.3	[-]	logSP [-44/-0.003]?=-999 Log of soft band false probability; Section 2.3
69-	76	F8.3	[-]	logHP [-42/-0.03]?=-999 Log of hard band false probability; Section 2.3
78-	85	F8.3	[-]	logFP [-44/-1.7]?=-999 Log of full band false probability; Section 2.3
87-	94	F8.3	[-]	logSdbP [-306/-0.003]?=-999 Log of deblended soft band false probability
96-	103	F8.3	[-]	logHdbP [-231/-0.03]?=-999 Log of deblended hard band false probability
105-	112	F8.3	[-]	logFdbP [-246/-1.7]?=-999 Log of deblended full band false probability
114	I1	---	dbf1	[0/1] Source remains significant after deblending flag (3) .
116-	122	F7.1	ct	Scts [8/11132] Total soft (3-8keV) band counts (4) .
124-	130	F7.3	ct	e_Scts [3/107] The 84% confidence level in Scts
132-	139	F8.3	ct	SBck [10/2568] Soft background counts scaled to source aperture (4) .
141-	148	F8.3	ct	SNet [5/9881] Net soft (3-8keV) band counts; Scts-SBck (4) .
150-	156	F7.3	ct	e_SNet [-99/107] The error in SNet (5) .
158-	163	F6.1	ct	Hcts [15/6680] Total hard (8-24keV) band counts (4) .
165-	170	F6.3	ct	e_Hcts [4/83] The 84% confidence level in Hcts
172-	179	F8.3	ct	HBck [7/1620] Hard background counts scaled to source aperture (4) .
181-	188	F8.3	ct	HNet [5/5854] Net hard (8-24keV) band counts; Hcts-HBck (4) .
190-	196	F7.3	ct	e_HNet [-99/83] The error in HNet (5) .
198-	204	F7.1	ct	Fcts [32/17765] Total full (3-24keV) band counts (4) .
206-	212	F7.3	ct	e_Fcts [6/135] The 84% confidence level in Fcts
214-	221	F8.3	ct	FBck [18/4178] Full background counts scaled to source aperture (4) .
223-	231	F9.3	ct	FNet [18/15694] Net full (3-24keV) band counts; Fcts-FBck (4) .
233-	239	F7.3	ct	e_FNet [-99/135] The error in FNet (5) .
241-	247	F7.1	ct	Sdbcts [8/11132] Total deblended soft band counts (4) .
249-	256	F8.3	ct	e_Sdbcts [10/2568] The 84% confidence level in Sdbcts
258-	265	F8.3	ct	SdbNet [5/9881] Net deblended soft band counts; Sdbcts-SdbBck (4) .
267-	273	F7.3	ct	e_SdbNet [-99/107] The error in SdbNet (5) .
275-	280	F6.1	ct	Hdbcts [15/6680] Total deblended hard band counts (4) .
282-	289	F8.3	ct	e_Hdbcts [7/1620] The 84% confidence level in Hdbcts
291-	298	F8.3	ct	HdbNet [5/5854] Net deblended hard band counts; Hdbcts-HdbBck (4) .
300-	306	F7.3	ct	e_HdbNet [-99/83] The error in HdbNet (5) .
308-	314	F7.1	ct	Fdbcts [32/17765] Total deblended full band counts (4) .
316-	323	F8.3	ct	e_Fdbcts [18/4178] The 84% confidence level in Fdbcts
325-	333	F9.3	ct	FdbNet [18/15694] Net deblended full band counts; Fdbcts-FdbBck (4) .
335-	341	F7.3	ct	e_FdbNet [-99/135] The error in FdbNet (5) .
343-	351	F9.1	s	Sexp [12556/] Soft band exposure time (6) .
353-	361	F9.1	s	Hexp [10166/] Hard band exposure time (6) .
363-	371	F9.1	s	Fexp [10172/] Full band exposure time (6) .
373-	381	E9.3	ct/s	SCR [0.0004/0.06] Total soft band count rate (7) .
383-	391	E9.3	ct/s	e_SCR [0.002] The 84% confidence level in SCR
393-	401	E9.3	ct/s	SCRbck [0.0004/0.007] Soft background count rate (7) .
403-	411	E9.3	ct/s	SNCR [0.06] Net soft count rate (7) .
413-	422	E10.3	ct/s	e_SNCR [-99/0.002] The error in SNCR (5) .
424-	432	E9.3	ct/s	HCR [0.0005/0.05] Total hard band count rate (7) .
434-	442	E9.3	ct/s	e_HCR [0.001] The 84% confidence level in HCR
444-	452	E9.3	ct/s	HCRbck [0.0006/0.005] Hard background count rate (7) .
454-	462	E9.3	ct/s	HNCR [0.04] Net hard count rate (7) .
464-	473	E10.3	ct/s	e_HNCR [-99/0.001] The error in HNCR (5) .
475-	483	E9.3	ct/s	FCR [0.001/0.2] Total full band count rate (7) .
485-	493	E9.3	ct/s	e_FCR [0.002] The 84% confidence level in FCR
495-	503	E9.3	ct/s	FCRbck [0.001/0.02] Full background count rate (7) .
505-	513	E9.3	ct/s	FNCR [0.0001/0.1] Net full count rate (7) .
515-	524	E10.3	ct/s	e_FNCR [-99/0.002] The error in FNCR (5) .
526-	534	E9.3	ct/s	SdbNCR [0.06] Deblended net soft count rate (7) .
536-	545	E10.3	ct/s	e_SdbNCR [-99/0.002] The 84% confidence level in SdbNCR
547-	555	E9.3	ct/s	HdbNCR [0.04] Deblended net hard count rate (7) .
557-	566	E10.3	ct/s	e_HdbNCR [-99/0.001] The 84% confidence level in HdbNCR

568-576	E9.3	ct/s	FdbNCR	[0.0001/0.1] Deblended net full count rate (7) .
578-587	E10.3	ct/s	e_FdbNCR	[-99/0.002] The 84% confidence level in FdbNCR
589-593	F5.3	---	H/S	[/7.5]?=0 Hard to Soft band ratio
595-601	F7.3	---	E_H/S	[-99/1] Upper error on H/S (8) .
603-609	F7.3	---	e_H/S	[-99/1] Lower error on H/S (8) .
611-616	F6.3	---	gamma	[-0.5/3]? Effective photon index
618-624	F7.3	---	E_gamma	[-99/1]? Upper error on gamma (8) .
626-632	F7.3	---	e_gamma	[-99/0.6]? Lower error on gamma (8) .
634-642	E9.3	mW/m2	SFlux	Observed-frame soft flux (9) .
644-653	E10.3	mW/m2	e_SFlux	?=-99 The 84% confidence level in SFlux
655-663	E9.3	mW/m2	HFlux	Observed-frame hard flux (9) .
665-674	E10.3	mW/m2	e_HFlux	?=-99 The 84% confidence level in HFlux
676-684	E9.3	mW/m2	FFlux	Observed-frame full flux (9) .
686-695	E10.3	mW/m2	e_FFlux	?=-99 The 84% confidence level in FFlux
697-704	A8	---	XOrig	Soft X-ray counterpart code (10) .
706-715	F10.6	deg	RAXdeg	? Soft X-ray counterpart Right Ascension in decimal degrees (J2000)
717-726	F10.6	deg	DEXdeg	? Soft X-ray counterpart Declination in decimal degrees (J2000)
728-732	F5.2	arcsec	XOff	[0.5/37]? Soft X-ray and NuSTAR position offset
734-742	E9.3	mW/m2	XFlux	[0/2e-12]? Observed-frame 3-8 keV X-ray counterpart flux (11) .
744-752	E9.3	mW/m2	XTFflux	[0/2e-12]? Total combined 3-8 keV X-ray flux within 30" of NUSTAR
754-763	F10.6	deg	RAWdeg	? WISE counterpart Right Ascension in decimal degrees (J2000)
765-774	F10.6	deg	DEWdeg	? WISE counterpart Declination in decimal degrees (J2000)
776-780	F5.3	arcsec	IROff	[0.05/6]? WISE and NuSTAR position offset
782-787	F6.3	mag	W1mag	[5.6/18.8]? WISE W1 band, 3.4um, profile-fit Vega magnitude
789-793	F5.3	mag	e_W1mag	[0.02/0.3]? Error in W1mag (12) .
795-800	F6.3	mag	W2mag	[3.8/17.4]? WISE W2 band, 4.6um, profile-fit Vega magnitude
802-806	F5.3	mag	e_W2mag	? Error in W2mag (12) .
808-813	F6.3	mag	W3mag	[4/14]? WISE W3 band, 12 micron, profile-fit Vega magnitude
815-819	F5.3	mag	e_W3mag	? Error in W3mag (12) .
821-826	F6.3	mag	W4mag	[1.7/10.2]? WISE W4 band, 22um, profile-fit Vega magnitude
828-832	F5.3	mag	e_W4mag	? Error in W4mag (12) .
834-842	A9	---	OOrig	Adopted optical counterpart code (13) .
844-855	F12.8	deg	RAOdeg	? Optical counterpart Right Ascension in decimal degrees (J2000)
857-868	F12.8	deg	DEOdeg	? Optical counterpart Declination in decimal degrees (J2000)
870-874	F5.3	arcsec	OOff	[0.02/6]? Optical and NuSTAR position offset
876-882	F7.3	mag	Rmag	[-99/24.3]? Optical counterpart R band Vega magnitude (14) .
884-888	F5.3	---	zsp	[0/3.5]? Spectroscopic redshift (15) .
890-899	E10.3	10-7W	XLum	? Rest-frame 10-40 keV luminosity (16) .
901	I1	---	PF1	[0/1] Source associated with primary science target (17) .
903	I1	---	A15F1	[0/1] Aird+ 2015ApJ...815...66A flag (18) .

Note (1): A binary flag indicating whether the source is detected with a false probability lower than our threshold of $\log(\text{PFalse})=-6$.

Note (2): Same as previous columns but after deblending has been performed to account for contamination of the source counts from very nearby sources (see Section 2.4 of this paper, and Section 2.3.2 of Mullaney+ (2015, [J/ApJ/808/184](#)). Deblending only affects a very small fraction of the overall sample (e.g., see Section 2.4).

Note (3): A binary flag indicating whether the NuSTAR detected source remains significant after deblending, in at least one of the three standard energy bands.

Note (4): Calculated at the source coordinates, and using a source aperture of 30" radius (see Section 2.4). The values are non-aperture-corrected; i.e., they correspond to the 30" values, and have not been corrected to the full PSF values.

Note (5): For the net source counts, we give 90% CL upper limits for sources not detected in a given band. Throughout the table, upper limits are flagged with a -99 value in the error column.

Note (6): The average net, vignetting-corrected exposure time at the source coordinates. These correspond to the A+B data, so should be divided by two to obtain the average exposure per FPM.

Note (7): Non-aperture-corrected. Determined from the photometric values and the exposure times.

Note (8): Upper limits, lower limits, and sources with no constraints are flagged with -99, -88, and -77 values, respectively, in the error columns.

Note (9): After deblending has been performed. These are aperture corrected values (i.e., they correspond to the full NuSTAR PSF), and are calculated from the count rates using the conversion factors listed in Section 2.4.

Note (10): An abbreviated code indicating the origin of the adopted soft (i.e., low energy; $<10\text{keV}$) X-ray counterpart. Code as follows:

CXO_CSC = counterparts from the Chandra Source Catalog (CSC; 82 occurrences; Evans+ 2010, Cat. [IX/45](#)).

XMM_3XMM = counterparts from the third XMM-Newton serendipitous source catalog (3XMM; 203 occurrences; Watson+ 2009, [J/A+A/493/339](#); Rosen+ 2016, [IX/50](#)).

CXO_MAN = sources manually identified using archival Chandra (27 occurrences)
 XMM_MAN = sources manually identified using archival XMM-Newton
 (24 occurrences)
 XRT_MAN = sources manually identified using archival Swift XRT data
 (60 occurrences).

Section 3.1 details the counterpart matching.

Note (11): For sources with counterparts in the CSC and 3XMM catalogs. For CSC sources we convert to the 3-8keV flux from the 2-7keV flux using a conversion factor of 0.83, and for the 3XMM sources we convert from the 4.5-12keV flux using a conversion factor of 0.92.

Note (12): Blanks in the errors indicates the magnitude is a WISE upper limit.

Note (13): An abbreviated code indicating the origin of the adopted optical counterpart to the NuSTAR source. Code as follows:

SDSS = sources with soft X-ray counterparts and successful matches in the SDSS DR7 catalog (York+ [2000AJ...120.1579Y](#)); 127 occurrences
 USNO = sources with soft X-ray counterparts and successful matches in the USNOB1 catalog (Monet+ 2003, [1/284](#)); 166 occurrences
 MAN = sources with a soft X-ray counterpart and a corresponding optical counterpart manually identified in the available optical coverage; 181 occurrences
 SDSS_WISE = there is no soft X-ray counterpart to the NuSTAR position, but a WISE AGN candidate is identified within the NuSTAR error circle and successfully matched to the SDSS DR7 (these are mainly used as candidates for spectroscopic followup); 11 occurrences.
 USNO_WISE = there is no soft X-ray counterpart to the NuSTAR position, but a WISE AGN candidate is identified within the NuSTAR error circle and successfully matched to the USNOB1 catalog (these are mainly used as candidates for spectroscopic followup; 6 occurrences).
 We give a detailed description of the procedure used to identify optical counterparts in Section 3.2.

Note (14): For the SDSS DR7 matches, this is calculated as $R=r-0.16$. For the USNOB1 matches, this is taken as the mean of the two independent photographic plate measurements, R1mag and R2mag. For the manual identifications, the magnitude is taken from another optical catalog or manually determined from the imaging data.

Note (15): The large majority of the redshifts were obtained through our own campaign of ground-based spectroscopic followup of NuSTAR serendipitous survey sources (see Section 3.3.1 and the "[Description](#)" section above).

Note (16): Estimated from the observed-frame fluxes, following the procedure outlined in Section 2.4. Negative values indicate upper limits. The luminosities are observed values, uncorrected for any absorption along the line of sight. The intrinsic luminosities may therefore be higher, for highly absorbed AGNs.

Note (17): A binary flag indicating the few sources which show evidence for being associated with the primary science targets of their respective NuSTAR observations, according to the definition in Section 2.3 [$\Delta(cz) < 0.05cz$].

Note (18): A binary flag highlighting the sources used in the Aird+ ([2015ApJ...815...66A](#)) study.

Byte-by-byte Description of file: [table\[68\].dat](#)

Bytes	Format	Units	Label	Explanations
1- 3	I3	---	Seq	[1/498] Unique source identification number
5- 10	A6	---	---	[NuSTAR]
11- 24	A14	---	NuSTAR	Unique NuSTAR source name (JHHMSS+DDMM.m)
26- 30	F5.3	---	z	[0/3.5]? Source spectroscopic redshift
32- 38	A7	---	Type	Classification (1) .
41-162	A122	---	Lines	Emission/absorption lines identified (2) .
164-231	A68	---	Notes	Source notes and literature spectra references
233-234	A2	---	Run	Unique observing run identification number (3) .

Note (1): Classification (for primary sources) as follows:

BL = broad-line AGN (151 occurrences + 11 BL?)
 NL = narrow-line AGN (84 occurrences + 13 NL?)
 BL Lac? = BL Lac object candidate (1 occurrence)
 Gal = galaxies (16 occurrences)
 See Section 3.3.2 for further details.

Note (2): Absorption line/feature marked with "dg" footnote.

Note (3): As defined in Table 4 ("S" and "L" mark spectra obtained from the SDSS and from elsewhere in the literature, respectively).

Byte-by-byte Description of file: [table7.dat](#)

Bytes	Format	Units	Label	Explanations
1- 2	I2	---	Seq	[1/64] Unique source identification number
4- 9	A6	---	---	[NuSTAR]
10- 23	A14	---	NuSTAR	Unique NuSTAR source name (JHHMSS+DDMM.m)
25- 34	F10.6	deg	RAdeg	Right Ascension in decimal degrees (J2000)

36- 45	F10.6	deg	DEdeg	Declination in decimal degrees (J2000)
47- 54	F8.3	ct	Scts	[36/7049]? Total soft band (3-8keV) counts (1).
56- 63	F8.3	ct	SBck	? Soft background counts (1).
65- 72	F8.3	ct	SNet	[16/6633]? Net soft band counts (1).
74- 80	F7.3	ct	e_SNet	[-99/85]? The error in SNet (2).
82- 89	F8.3	ct	Hcts	? Total hard band (8-24 keV) counts (1).
91- 98	F8.3	ct	HBck	? Hard background counts (1).
100-107	F8.3	ct	HNet	[13/4306]? Net hard band counts (1).
109-115	F7.3	ct	e_HNet	[-99/69]? The error in HNet (2).
117-125	F9.3	ct	Fcts	[85/11617]? Total full band (3-24keV) counts (1).
127-134	F8.3	ct	FBck	? Full background counts (1).
136-144	F9.3	ct	FNet	[22/10900]? Net full band counts (1).
146-152	F7.3	ct	e_FNet	[-99/109]? The error in FNet (2).
154-161	F8.1	s	Sexp	[14375/643091]? Soft band exposure time (3).
163-170	F8.1	s	Hexp	? Hard band exposure time (3).
172-179	F8.1	s	Fexp	? Full band exposure time (3).
181-189	E9.3	ct/s	SNCR	[0.0003/0.5]? Net soft count rate, aperture-corrected (4).
191-200	E10.3	ct/s	e_SNCR	[-99/0.006]? The error in SNCR (2).
202-210	E9.3	ct/s	HNCR	[0.0003/0.4]? Net hard count rate, aperture-corrected (4).
212-221	E10.3	ct/s	e_HNCR	[-99/0.006]? The error in HNCR (2).
223-231	E9.3	ct/s	FNCR	[0.0005/1]? Net full count rate, aperture-corrected (4).
233-242	E10.3	ct/s	e_FNCR	[-99/0.01]? The error in FNCR (2).
244-252	E9.3	mW/m2	SFlux	? Observed-frame soft flux (5).
254-263	E10.3	mW/m2	e_SFlux	[-99/]? The 84% confidence level in SFlux
265-273	E9.3	mW/m2	HFlux	? Observed-frame hard flux (5).
275-284	E10.3	mW/m2	e_HFlux	[-99/]? The 84% confidence level in HFlux
286-294	E9.3	mW/m2	FFlux	? Observed-frame full flux (5).
296-305	E10.3	mW/m2	e_FFlux	[-99/]? The 84% confidence level in FFlux
307-309	A3	---	XName	Lower energy X-ray counterpart observatory name
311-320	F10.6	deg	RAXdeg	? Lower energy X-ray counterpart Right Ascension in decimal degrees (J2000)
322-331	F10.6	deg	DEXdeg	? Lower energy X-ray counterpart Declination in decimal degrees (J2000)
333-336	A4	---	OName	Other, optical or WISE, counterpart observatory name
338-347	F10.6	deg	RAOdeg	? Other counterpart Right Ascension in decimal degrees (J2000)
349-358	F10.6	deg	DEOdeg	? Other counterpart Declination in decimal degrees (J2000)
360-364	F5.3	---	zsp	[0/1.9]? Spectroscopic redshift (6).
366-375	E10.3	10-7W	XLum	? Non-absorption-corrected, rest-frame 10-40keV luminosity (7).
377	A1	---	F1	Primary catalog code (8).

Note (1): Calculated at the source coordinates. The values are non-aperture-corrected.

Note (2): For the net source counts, we give 90% CL upper limits for sources not detected in a given band. Throughout the table, upper limits are flagged with a -99 value in the error column. The photometric columns are blank where the A+B data prohibit reliable photometric constraints.

Note (3): The average net, vignetting-corrected exposure time at the source coordinates. These correspond to the A+B data, so should be divided by two to obtain the average exposure per FPM.

Note (4): Determined from the photometric values and the exposure times.

Note (5): After deblending has been performed. These are aperture corrected values (i.e., they correspond to the full NuSTAR PSF), and are calculated from the count rates using the conversion factors listed in Section 2.4.

Note (6): The large majority of the redshifts were obtained through our own campaign of ground-based spectroscopic followup of NuSTAR serendipitous survey sources (see Section 3.3.1 and the "Description" section above).

Note (7): Estimated from the observed-frame fluxes, following the procedure outlined in Section 2.4. Negative values indicate upper limits. The luminosities are observed values, uncorrected for any absorption along the line of sight. The intrinsic luminosities may therefore be higher, for highly absorbed AGNs.

Note (8): A character indicating the reason for not being included in the primary catalog. These are categorised into four groups as follows:

- E = the source is within or very close to the peripheral region of the NuSTAR mosaic, which is excluded from the primary source detection (33% of cases);
- T = the source is narrowly offset from the central science target position for the NuSTAR observation (and thus automatically excluded; see Section 2.3), or from another bright source in the field (11%);
- X = the source lies in a region which is masked out, or in a NuSTAR field which is excluded, from the primary source detection (44%; e.g., due to highly contaminating stray light or a bright science target); or
- L = the source has a comparatively low detection significance (12%).

History:

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Prepared by [AAS], Emmanuelle Perret [CDS] 15-Sep-2017

The document above follows the rules of the [Standard Description for Astronomical Catalogues](#); from this documentation it is possible to generate *f77* program to load files [into arrays](#) or [line by line](#).

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