VARIABILITY OF ULTRA-LUMINOUS X-RAY SOURCES

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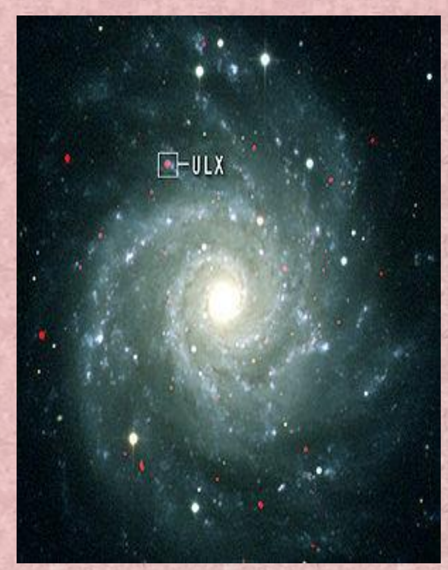
Chandra observations of 17 nearby galaxies were analyzed and 166 bright sources with X-ray counts > 100 , were chosen for temporal analysis. Fractional root mean square variability was estimated for the lightcurves binned at ~ 4 ksec and of length ~ 40 ksec. Eight sources (of which three are ultra-luminous X-ray sources (ULX) with unabsorbed luminosity L > 10^{39} ergs/sec) , were found to be variable at a significance level greater than 2-sigma. For six sources the variability is primarily dominated by either a secular change or a single flare like activity while for two sources (one in NGC0628 and the other in NGC1569) the variability is dominated by large amplitude fluctuations. While the source in NGC1569 has a relatively low luminosity of L ~ 10^{38} ergs/sec , the one in NGC0628 is a unique ULX in the sample . The other two variable ULX have ultra-soft spectra with temperature < 0.3 keV. There are 10 ULX in sample for which the fractional r.m.s variability is constrained to be < 10 % . These result seem to indicate that ULX are typically not highly variable in k-sec timescales, except for some ultra-soft ones. The uniqueness of the rapidly varying source in NGC0628 , which has been compared earlier to the Galactic micro-quasar GRS 1915+105, reveals the rarity of such systems.

What are Ultra-Luminous X-ray Sources?

- Point like non-nuclear X-ray sources
- Thought to be X-ray binaries containing black holes
- L_x > 10^{39} erg/sec (above Eddington limit for 10 solar mass black holes)



composite X-ray/optical image of M74(NASA/CXC)

Sample selection , data reduction and analysis

- Chandra observation of 17 nearby galaxies were analyzed by using CIAO
- 166 sources with counts > 100 were chosen for temporal analysis
- Extracted lightcurves for time bin of 4 ksec and of length ~ 40 ksec
- Variance was computed to differentiate the variable and non-variable sources

TABLE 1
SAMPLE GALAXY PROPERTIES

Galaxy	Distance (Mpc)	ObsID	$T_{exp}(ks)$	N($\geq 100cts$)
NGC0628	9.7	2058	46.16	5
NGC0891	10.0	794	50.90	12
NGC1291	8.9	795	39.16	6
NGC1399	18.3	319	55.94	27
NGC1569	2.2	782	96.75	11
NGC2403	3.1	2014	35.59	2
NGC3556	14.1	2025	59.36	14
NGC3628	10.0	2039	57.96	9
NGC4125	24.2	2071	64.23	6
NGC4365	20.9	2015	40.42	3
NGC4579	21.0	807	33.90	3
NGC4631	7.6	797	59.21	6
NGC4649	16.6	785	36.87	13
NGC4697	11.8	784	39.25	8
NGC5128	4.0	962	36.50	17
NGC5775	26.7	2940	58.21	12
NGC6946	5.5	1043	58.28	12

NOTE. — (T_{exp})the exposure time in ks; (N) the number of point sources with total counts from the source > 100

TABLE 2
SPECTRAL PROPERTIES OF POINT SOURCES FITTED WITH THE POWER-LAW MODEL

Galaxy	Source Name	R.A.	Decl.	$n_H(10^{22}cm^{-2})$	Γ	log(L) ergs/s	C_{stat}	d. o. f.	F_{var}
NGC1399	S1	3 38 31.73	-35 30 58.65	$0.01^{+0.16}_{-0.01}$	$2.52^{+1.65}_{-0.55}$	$38.56^{+0.50}_{-0.11}$	5.68	2	$1.16^{1.38}_{0.90}$
NGC1569	S2	4 30 48.14	+64 50 50.57	$0.51^{+0.06}_{-0.06}$	$4.06^{+0.33}_{-0.22}$	$38.66^{+0.19}_{-0.15}$	88.44	50	$0.76^{0.83}_{0.67}$
NGC1569	S3	4 30 48.62	+64 50 58.59	$0.24^{+0.06}_{-0.05}$	$1.64^{+0.22}_{-0.11}$	$37.72^{+0.03}_{-0.02}$	36.90	33	$0.64^{0.72}_{0.55}$
NGC0628	S4	1 36 47.45	+15 47 45.01	$0.89^{+0.11}_{-0.33}$	$9.56^{+0.44}_{-2.42}$	$42.18^{+0.36}_{-1.49}$	8.56	4	$0.50^{0.65}_{0.28}$
NGC5128	S5	13 25 27.52	-43 02 14.78	$0.02^{+0.08}_{-0.02}$	$1.75^{+0.44}_{-0.33}$	$38.00^{+0.06}_{-0.04}$	3.38	4	$0.36^{0.51}_{0.11}$
NGC2403	S6	7 37 11.63	+65 33 45.52	$0.63^{+0.26}_{-0.18}$	$2.30^{+0.44}_{-0.33}$	$38.39^{+0.21}_{-0.12}$	21.83	13	$0.35^{0.45}_{0.20}$
NGC0628	S7	1 36 51.06	+15 45 46.86	$0.03^{+0.05}_{-0.03}$	$1.86^{+0.22}_{-0.11}$	$39.22^{+0.04}_{-0.02}$	50.58	36	$0.25^{0.31}_{0.16}$
NGC6946	S8	20 35 0.13	+60 09 07.97	$0.61^{+0.06}_{-0.05}$	$5.14^{+0.34}_{-0.27}$	$40.41^{+0.21}_{-0.18}$	134.85	63	$0.16^{0.21}_{0.08}$

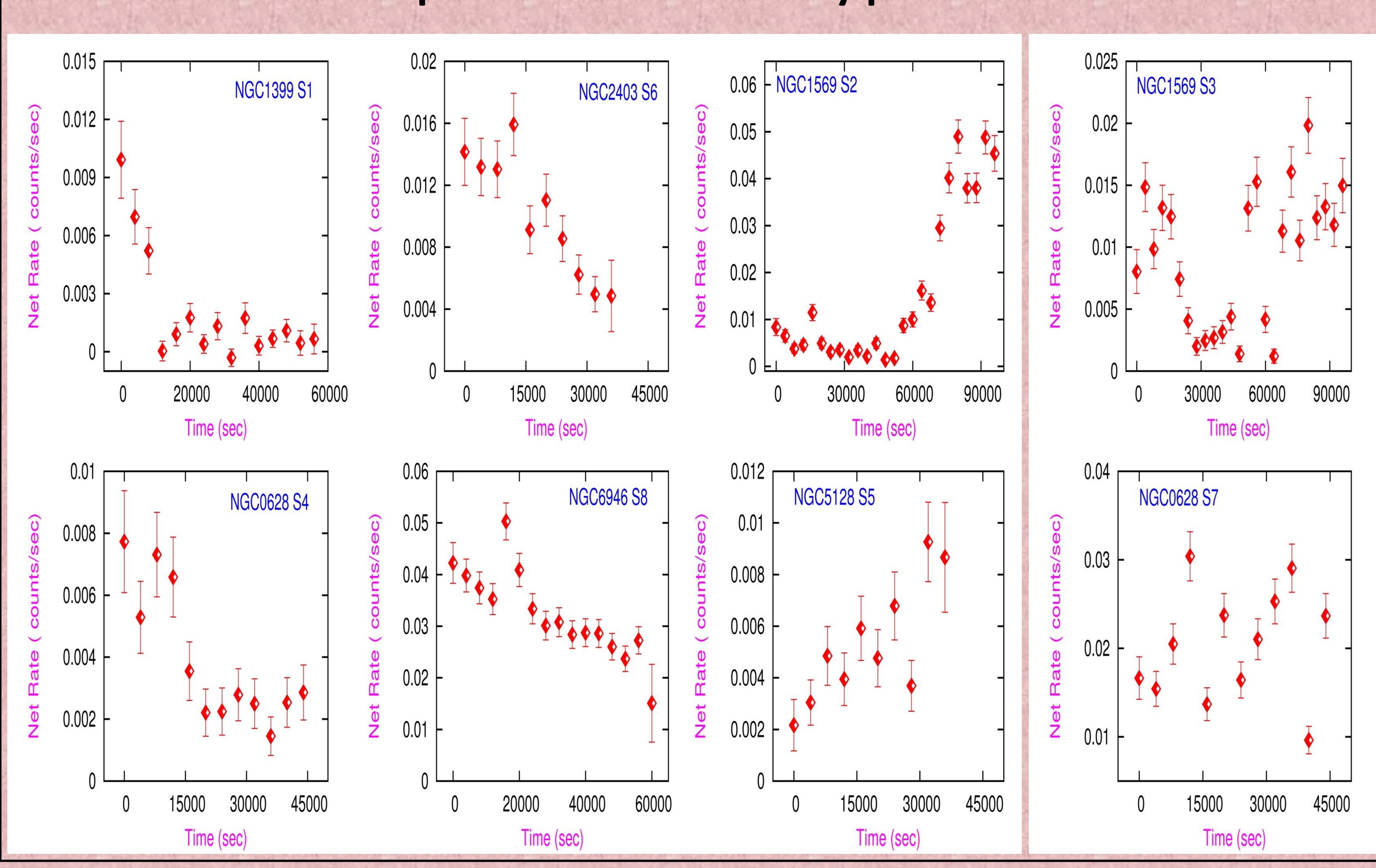
NOTE. — Host galaxy name; Source Name; Right Ascension; Declination; n_H- equivalent hydrogen column density; Γ- photon power-law index; L- X-ray luminosity in the energy range: 0.3-8.0 keV; C-statistics; d.o.f-degree of freedom; F_{var}-fractional root mean square (rms) variability amplitude.

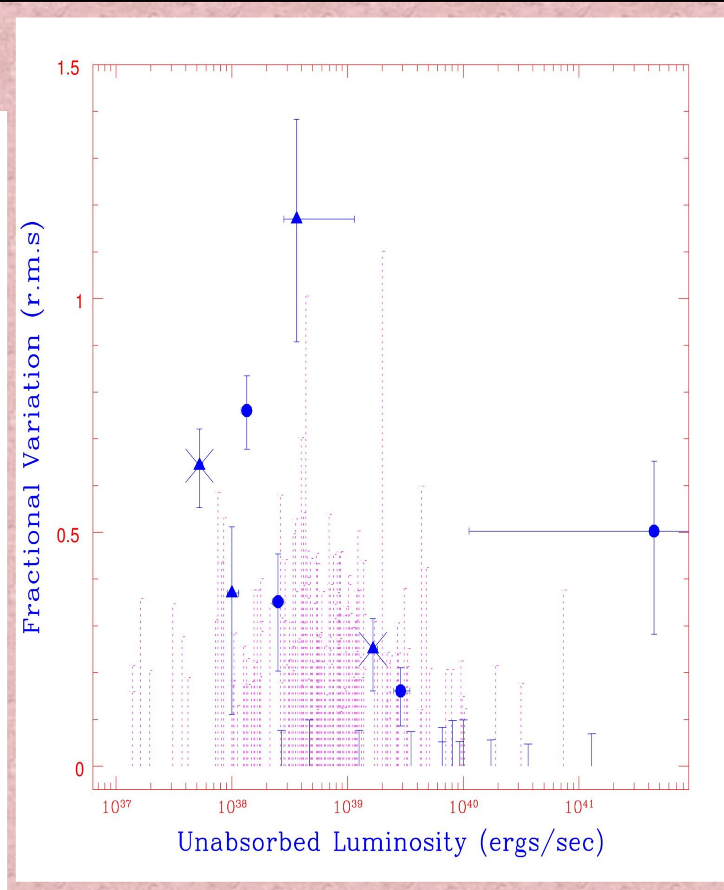
TABLE 3
SPECTRAL PROPERTIES OF POINT SOURCES FITTED WITH THE DISK BLACK BODY MODEL

Galaxy	Source Name	R.A.	Decl.	$n_H(10^{22}cm^{-2})$	kT_{in} (keV)	log(L) ergs/s	C_{stat}	d. o. f.	F_{var}
NGC1399	S1	3 38 31.73	-35 30 58.65	$0.00^{+0.06}_{-0.00}$	$0.25^{+0.06}_{-0.06}$	$38.82^{+0.26}_{-0.02}$	4.66	2	$1.16^{1.38}_{0.90}$
NGC1569	S2	4 30 48.14	+64 50 50.57	$0.19^{+0.02}_{-0.03}$	$0.41^{+0.04}_{-0.03}$	$38.13^{+0.04}_{-0.05}$	97.93	50	$0.76^{0.83}_{0.67}$
NGC1569	S3	4 30 48.62	+64 50 58.59	$0.10^{+0.04}_{-0.05}$	$1.68^{+0.30}_{-0.19}$	$37.96^{+0.04}_{-0.04}$	50.02	33	$0.64^{0.72}_{0.55}$
NGC0628	S4	1 36 47.45	+15 47 45.01	$0.75^{+0.58}_{-0.39}$	$0.09^{+0.04}_{-0.03}$	$41.65^{+2.49}_{-1.60}$	0.66	4	$0.50^{0.65}_{0.28}$
NGC5128	S5	13 25 27.52	-43 02 14.78	$0.00^{+0.10}_{-0.00}$	$1.12^{+0.37}_{-0.23}$	$38.20^{+0.08}_{-0.05}$	5.92	4	$0.36^{0.51}_{0.11}$
NGC2403	S6	7 37 11.63	+65 33 45.52	$0.28^{+0.16}_{-0.14}$	$1.09^{+0.23}_{-0.15}$	$38.40^{+0.05}_{-0.05}$	19.06	13	$0.35^{0.45}_{0.20}$
NGC0628	S7	1 36 51.06	+15 45 46.86	$0.00^{+0.00}_{-0.00}$	$0.89^{+0.08}_{-0.11}$	$39.42^{+0.02}_{-0.04}$	119.44	36	$0.25^{0.31}_{0.16}$
NGC6946	S8	20 35 0.13	+60 09 07.97	$0.22^{+0.03}_{-0.03}$	$0.32^{+0.02}_{-0.03}$	$39.46^{+0.08}_{-0.06}$	162.24	63	$0.16^{0.21}_{0.08}$

NOTE. — Host galaxy name; Source Name; Right Ascension; Declination; n_H- equivalent hydrogen column density; kT_{in}- inner disk temperature; L- X-ray luminosity in the energy range: 0.3-8.0 keV; C-statistics; d.o.f-degree of freedom; F_{var}-fractional root mean square (rms) variability amplitude.

Temporal behavior of X-ray point sources





Δ → sources with spectra better modeled as a power- law

● → sources with spectra better modeled as a disk black body

× → sources with large amplitude fluctuation

- 8 sources were found to be variable
- Three are ULXs
- For 6 sources variability is dominated by either a secular change or single flare like activity
- For 2 sources variability is dominated by large amplitude fluctuations

ULX are typically not highly variable in ksec time scales , except for some ultra-soft one

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