X-ray Luminosity Evolution in Normal Elliptical Galaxies with c-COSMOS

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ABSTRACT

We investigate the X-ray luminosity of a well-defined sample of early type galaxies as a function of redshift with Chandra COSMOS data (Elvis et al. 2006). We carefully select high-redshift elliptical galaxies, based on their morphology, optical color, and the Kormendy relation (Scarlata et al. 2007). By stacking X-ray data at the positions of elliptical galaxies after excluding possible AGNs, we find that the average L_X / L_B increases by a factor of 2 to z=0.4 (or lookback time of ~5 Gyr), at a 3σ confidence level. This increase is slightly steeper than that expected from the previously determined $(1+z)^{2.7}$, but still consistent within the error. We also discuss the X-ray luminosity and its evolution in S0, E+A, optically (less-) luminous galaxy samples.

(related talk by S. Puccetti on Tuesday)

Early Type Galaxy selection

complete down to I_{AB} = 24 mag (see Sacarlata et al. 2007)

(1) MORPHOLOGICAL selection (total 9120 galaxies)
based on our structural analysis (ZEST),
identifies as early-type galaxies objects which have the structure of such systems, independent of the colors of their stellar populations

(2) PHOTOMETRICAL selection (total 15996 galaxies)
based on SED consideration
a "red sequence" selection, i.e., a criterion
that identifies early-type galaxies on the basis of their colors,
independent of their structural properties

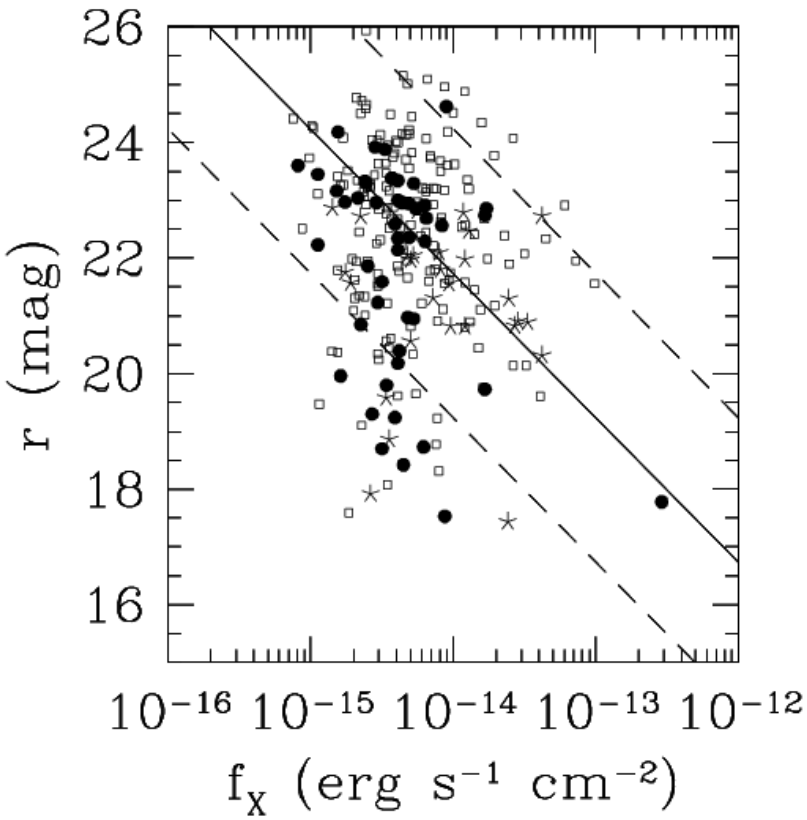
(3) Kormendy relation selection
select objects consistent with evolving into the z=0 Kormendy relation

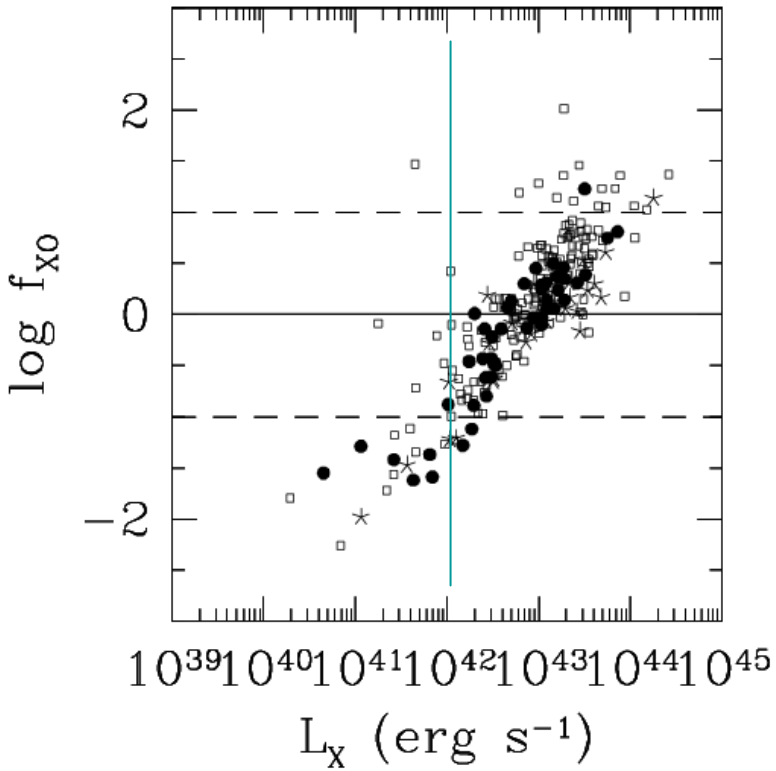
Selected Early Type Galaxies

Morphology	Photometry	Kormendy	# gal	
Y (E)	Y	Y	2580	E
Y (E)	Y	N	176	
Y (E)	N	Y	603	E+A
Y (E)	N	N	197	
Y (S0)	Y	Y	2480	S0
Y (S0)	Y	N	202	
Y (S0)	N	Y	806	S0+A (?)
Y (S0)	N	N	544	
N 1	Y	Y	3439	disk gal w/ a large bulge
N 2	Y	Y	621	intermediate
N 3	Y	Y	99	w/ a small bulge
N 1	Y	N	1834	
N 2	Y	N	2377	
N 3	Y	N	988	

E = morphologically E & selected by color and z=0 Kormendy relation
S0 = morphologically S0 & selected by color and z=0 Kormendy relation
E+A = morphologically E & satisfy z=0 Kormendy relation, but w/ blue color

Detected X-ray Source Properties



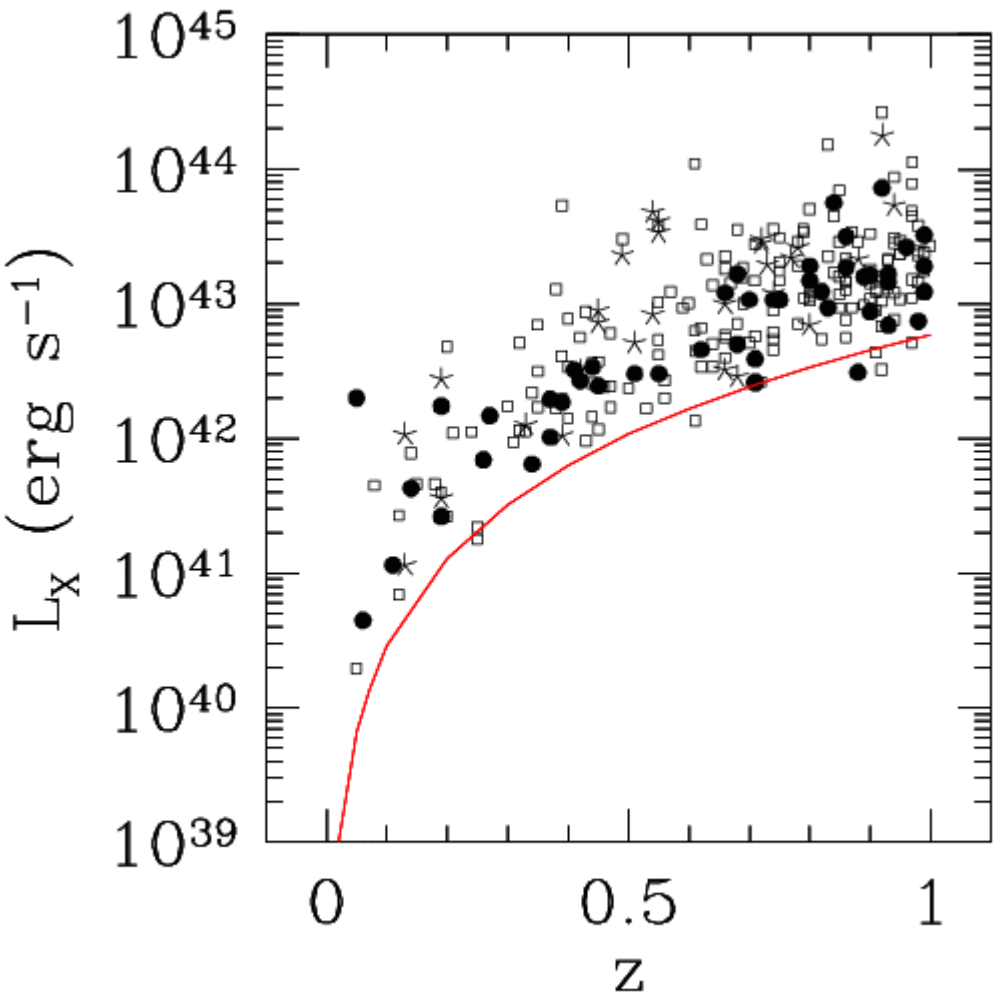


AGN contamination among Early Type Galaxy sample

AGNs found between *log Fxo* = ± 1 (dashed lines), or $L_X > 10^{42}$ erg s^{-1} (blue line)

Most AGNs are detected and removed in stacking up to z = 0.5

(Filled circles = E ; Stars = E+A) E+A : more X-ray luminous than E



Detection limit

Limiting sensitivity (red line)
10 counts for 100ksec exposure
~ corresponding to 90% det limit

AGN with $L_X > 10^{42}$ erg sec^{-1}
can be detected to z~0.5
can be removed from stacking

Our normal galaxy sample
reliably extends to **z < 0.4**
without AGN contamination

Stacking X-ray images for an Early Type Galaxy Sample

Detected point sources excluded

To most effectively remove AGN contaminations, we used an extensive sample (~3000 sources) with 5% chance probability of spurious sources

Also excluded are extended sources identified by visual inspection

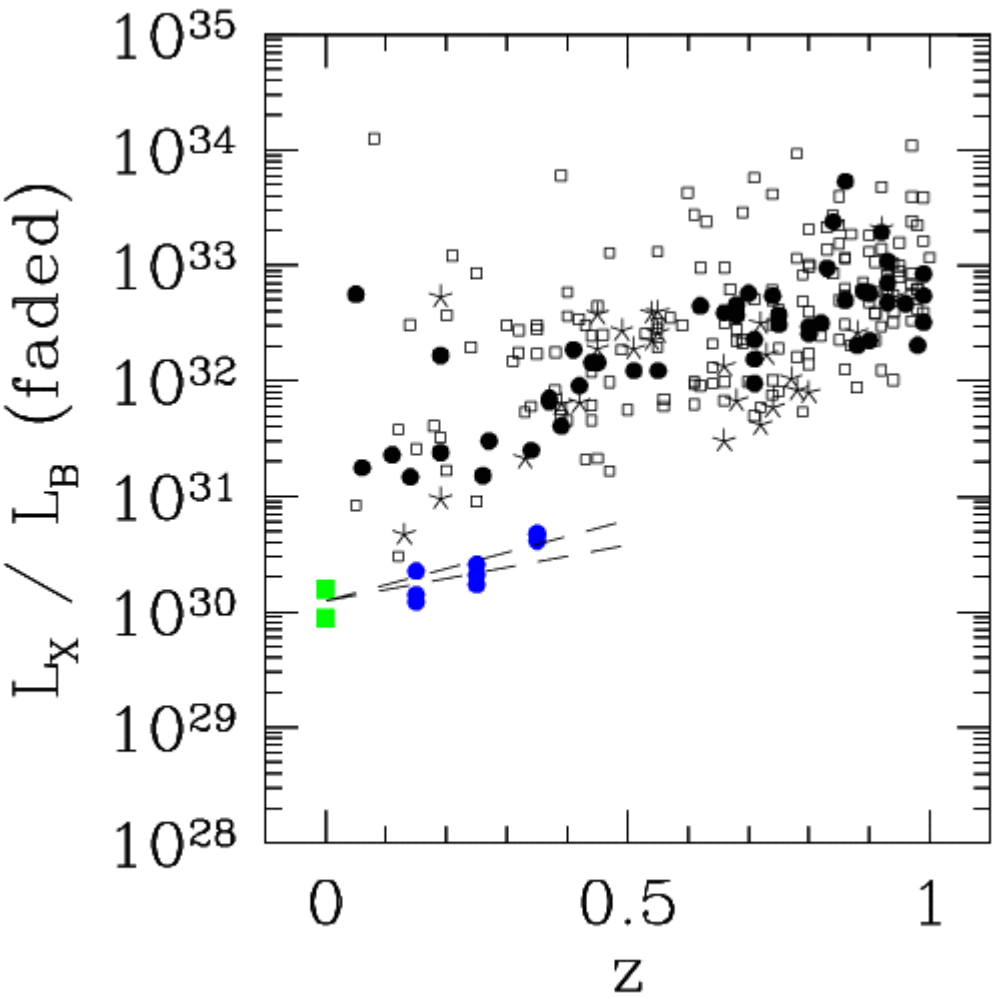
redshift bin size = 0.1 to z = 0.4

galaxies in each bin is up to 350 w/ effective exposure up to 50 Msec

➔ **signal detected as high as 6σ to z=0.4**

➔ **L_{XO} increases as a function of z ~ 3-4σ significance**

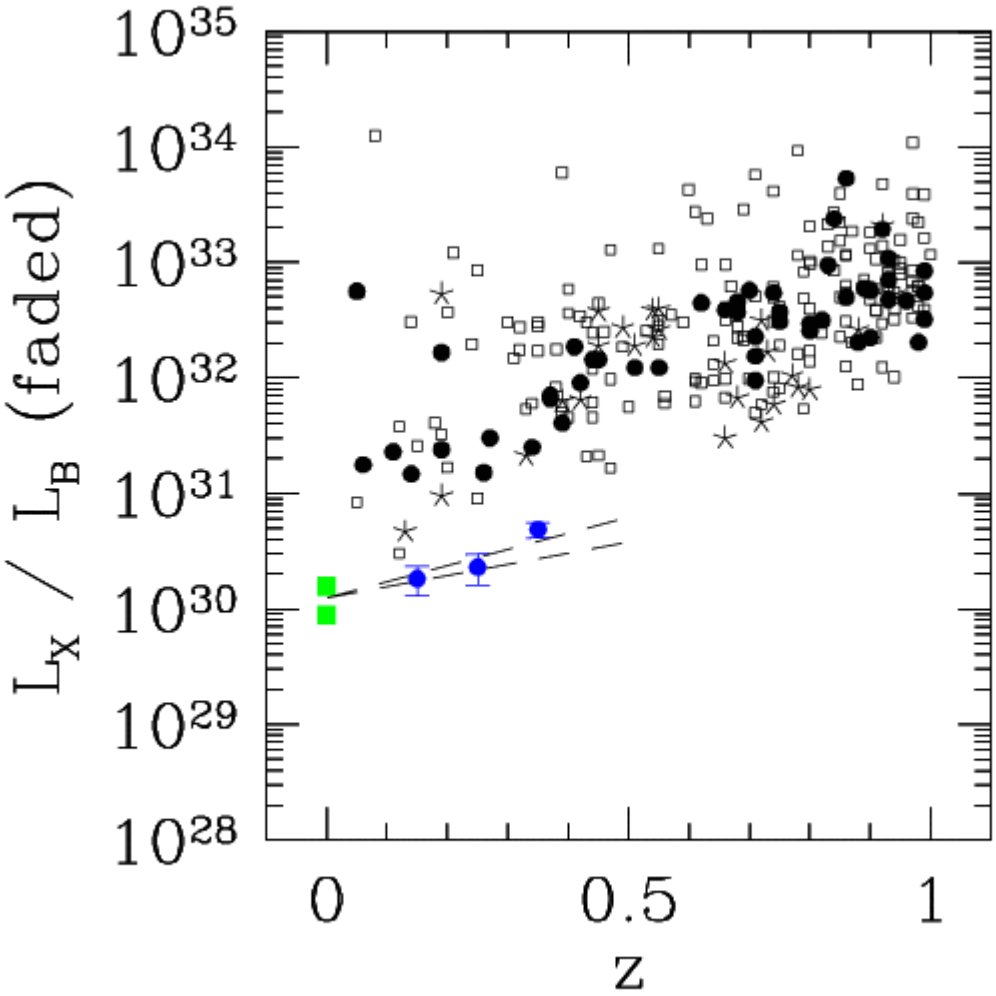
Also confirmed with a null hypothesis test by stacking random blank samples



Green squares =
Lxo at the local Universe z~0

Blue circles =
Lxo from our stacking of early type galaxy samples

dashed lines
Lxo ~ $(1+z)^{2.7}$ and $(1+z)^{4.0}$



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Stacking Results

z		N	sigma	exposure (Msec)	Fx (10^{-16})	r (mag)	Fxo (10^{-3})	Lx (10^{40})	M_B (MAG)	Lxo (10^{30})
E + S0 (morph-selected or color-selected)										
0.1	0.2	113	3.5	17.6	1.22	19.6	1.78	0.93	-19.2	1.22
0.2	0.3	150	3.3	23.1	1.10	20.3	3.07	2.30	-19.6	2.08
0.3	0.4	345	6.7	53.6	1.47	21.0	7.61	6.65	-19.9	4.82
E + S0 (morph and color-selected)										
0.1	0.2	66	3.3	10.2	1.44	19.5	1.89	1.15	-19.3	1.41
0.2	0.3	68	1.7	10.4	0.97	20.2	2.35	2.03	-19.7	1.72
0.3	0.4	202	4.7	31.4	1.32	20.9	5.96	5.94	-19.9	4.13
E (morph and color-selected)										
0.1	0.2	35	3.3	5.4	2.20	19.5	2.95	1.85	-19.3	2.25
0.2	0.3	32	2.2	4.9	1.70	20.0	3.43	3.48	-19.9	2.59
0.3	0.4	94	4.0	14.8	1.55	20.8	6.69	6.98	-20.0	4.69
S0 (morph and color-selected)										
0.1	0.2	31	1.0	4.8	0.59	19.5	0.76	0.44	-19.3	0.54
0.2	0.3	36	0.3	5.5	0.33	20.4	0.93	0.70	-19.6	0.66
0.3	0.4	108	2.7	16.6	1.12	20.9	5.26	5.03	-19.9	3.61

Mean L_{XO} in the Local Universe (at z~0)

- X-ray luminosity from LMXBs of local elliptical galaxies ~ total stellar luminosity
  (Kim & Fabbiano 2004)

$$L_X / L_B = 0.9 \times 10^{30} \text{ erg sec-1 } / L_{B\odot}$$

  This is a lower limit of mean L_{XO} at z~0 (hot ISM component not added)

- Average L_{XO} from the X-ray survey
  a. ChaMP galaxies by Kim et al. 2006

$$L_X / L_B = 1.35 \times 10^{30} \text{ erg sec}^{-1} / L_{B\odot}$$

  b. XMM Survey by Georgantopoulos et al. 2005

$$L_X / L_B = 1.16 \times 10^{30} \text{ erg sec}^{-1} / L_{B\odot}$$

  This is not a fair sample, since normal galaxies are selected based on F_{XO}.

- Einstein + ROSAT galaxy sample

$$L_X / L_B = 1.6 \times 10^{30} \text{ erg sec}^{-1} / L_{B\odot}$$

  This is an upper limit of mean L_{XO} at z~0 (X-ray faint galaxies not complete)

Other Discussions

Optically Luminous vs Optically Faint Galaxies

Lehmer et al. (2007) with 539 E-CDF-S early type galaxies at z < 0.7

L_X/L_B no evolution from z=0.7 to z=0 for opt luminous galaxies ($L_B > 10^{10}\ L_{B\odot}$)

suggestive evidence of increase for opt. faint galaxies ($L_B < 10^{10}\ L_{B\odot}$)

(by a factor of 5 ± 4)

The optically luminous gal sample shows the L_X/L_B evolution as in the total sample.
We do not detect a signal from the optically faint galaxy sample.

E vs S0

Ellipticals appear to be more X-ray luminous than S0; the trend continues to z=0.4

E+A

morphologically ellipticals, but with a blue color than the red sequence galaxies tend to be X-ray bright (Kim et al. 2006)

We do not detect a signal, but the upper limit still consistent to be X-ray bright