The X-ray Binary Populations of Early-type Galaxies

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X-ray–Emitting Components of Early-type Galaxies

Hot Gas: results from the heating of gas lost from stellar mass loss that is shock-heated to X-ray–emitting temperatures 0.3–1.0 keV ($3 \times 10^6 - 10^7$ K).

Point Sources: primarily low-mass X-ray binaries (LMXBs) consisting of a neutron star or black hole accreting material from a giant or sub-giant companion.

AGN: can range in luminosity from $< 10^{38}$ ergs s^{-1} to $\sim 10^{40}$ ergs s^{-1}.

The relative importance of each component varies strongly from galaxy to galaxy. Galaxies that are X-ray bright have large amounts of hot gas, while galaxies that are X-ray faint have had most of their hot gas removed, leaving LMXBs or the AGN as the dominant source of X-ray emission.

X-ray faint galaxies are the easiest in which to study the LMXB component of galaxies.

Sample and Spectral Results

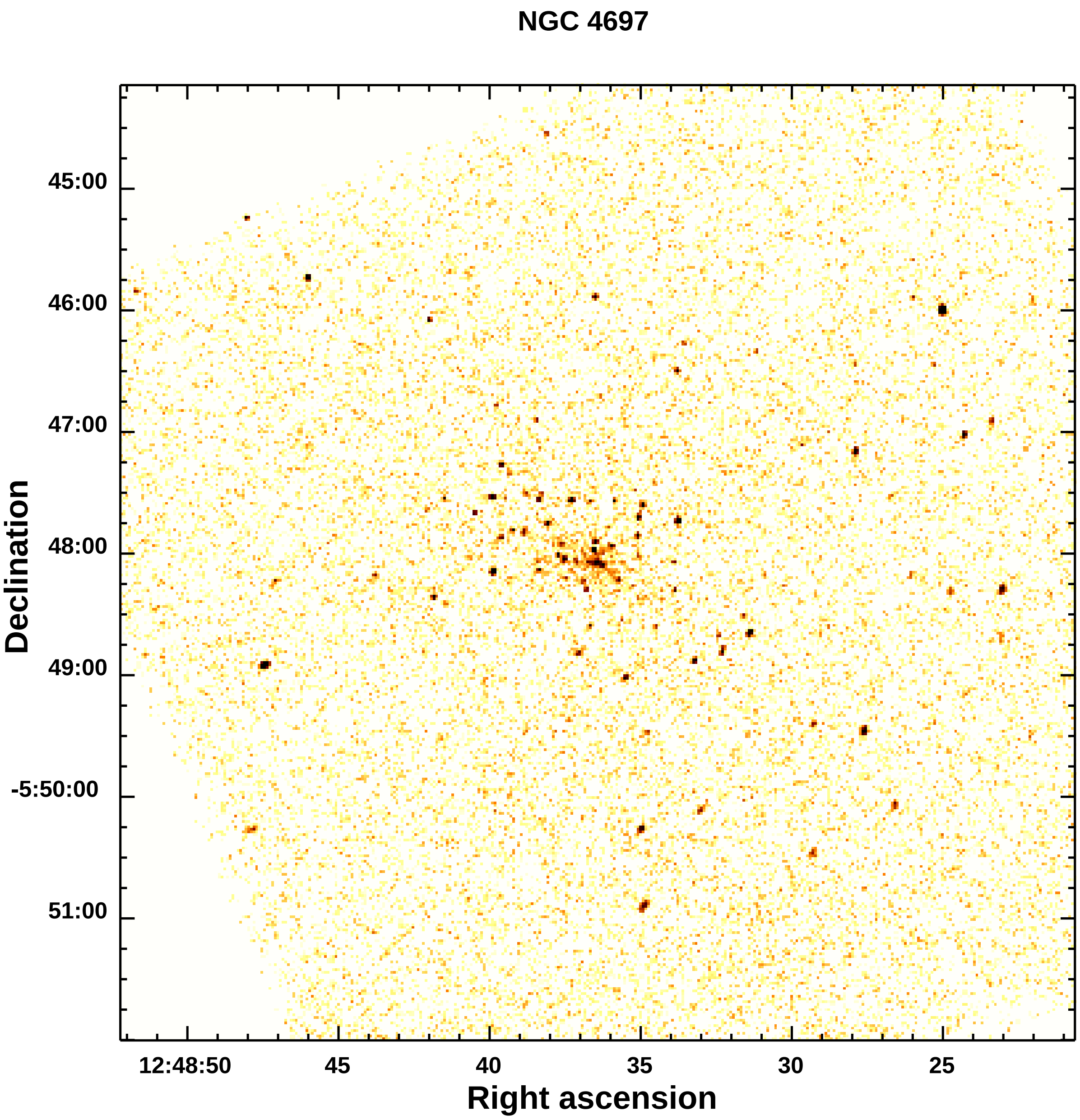
NGC 4697: E6 (Sarazin, Irwin, & Bregman 2000, 2001)
NGC 1553: S0 (Blanton, Sarazin, & Irwin 2001)
NGC 1291: Sa (Irwin, Sarazin, & Bregman 2001)
NGC 3115: S0
NGC 4494: E1
NGC 3585: E7/S0
NGC 2681: Sa (archival data)

The data were filtered to remove times of high background, and standard data reduction procedures were followed.

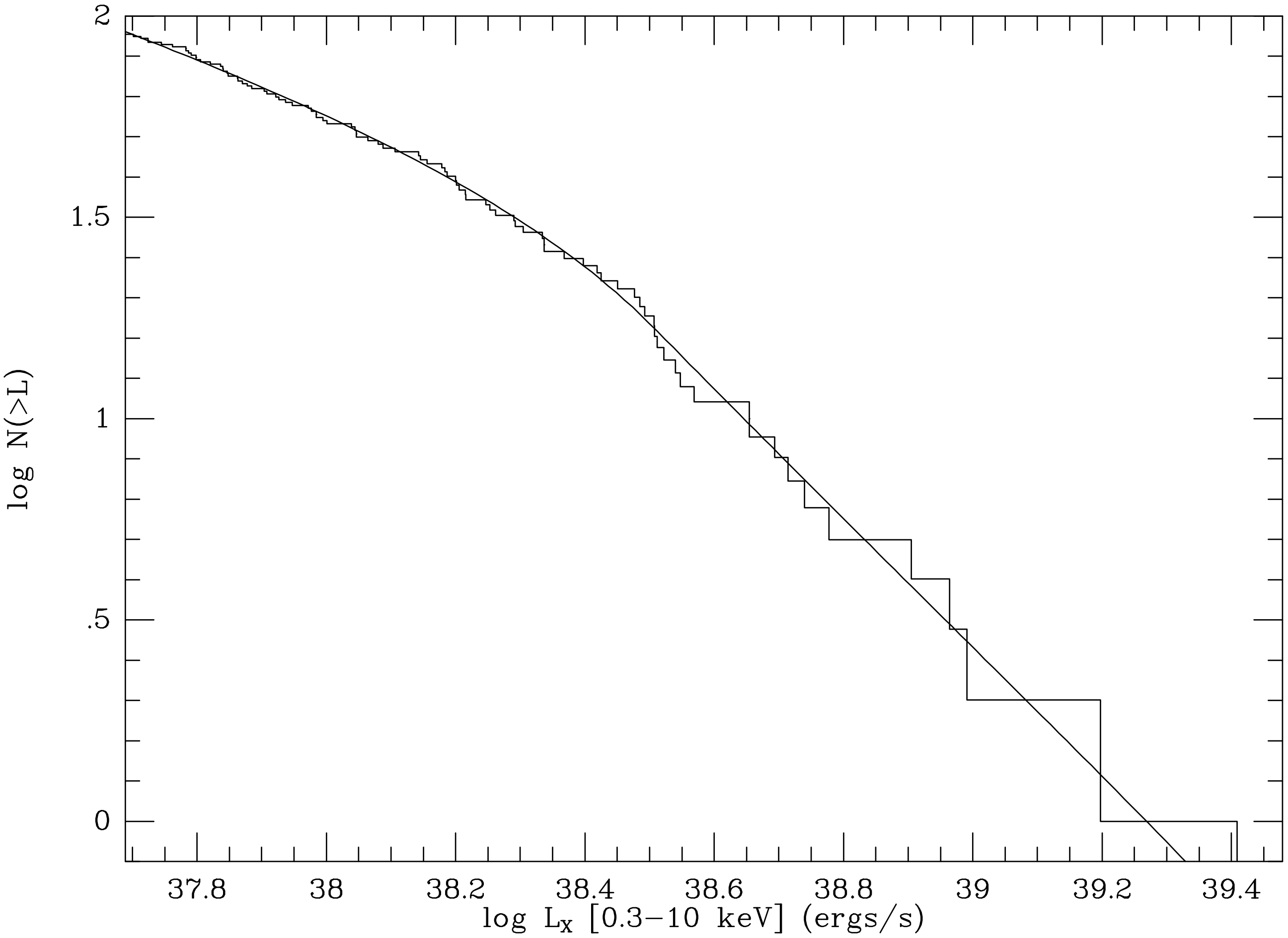
Sources identified both by eye and automated source detection techniques, and a detection threshold of 3σ was chosen (corresponding to $\sim$ 10 X-ray photons).

The limiting luminosity is set by the distance of the source and length of the observation ($2 \times 10^{37} - 2 \times 10^{38}$ ergs s^{-1}), yielding 10–90 X-ray sources.

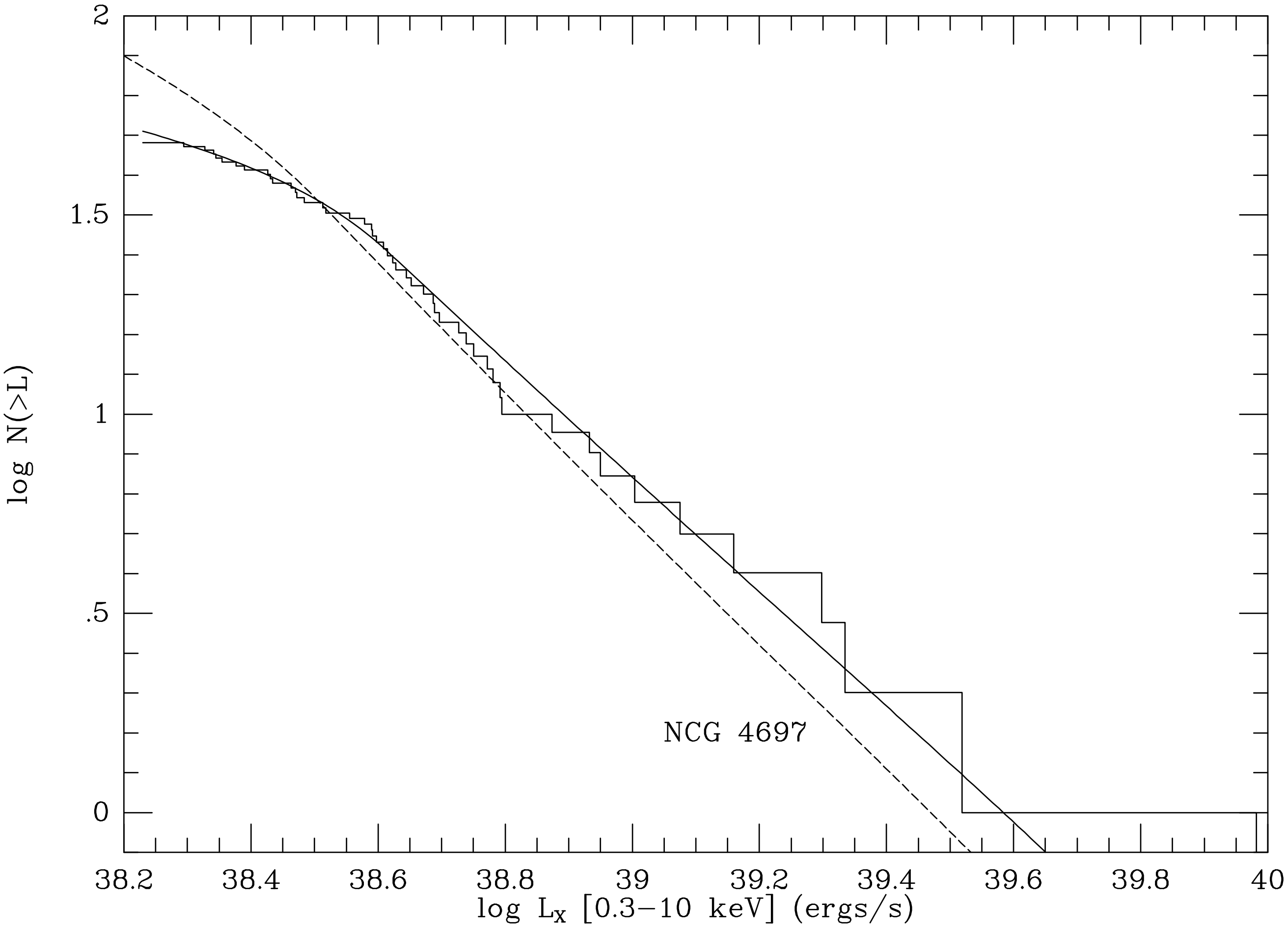
Spectra were fit well with a power law with an exponent $\Gamma \sim 1.6$.



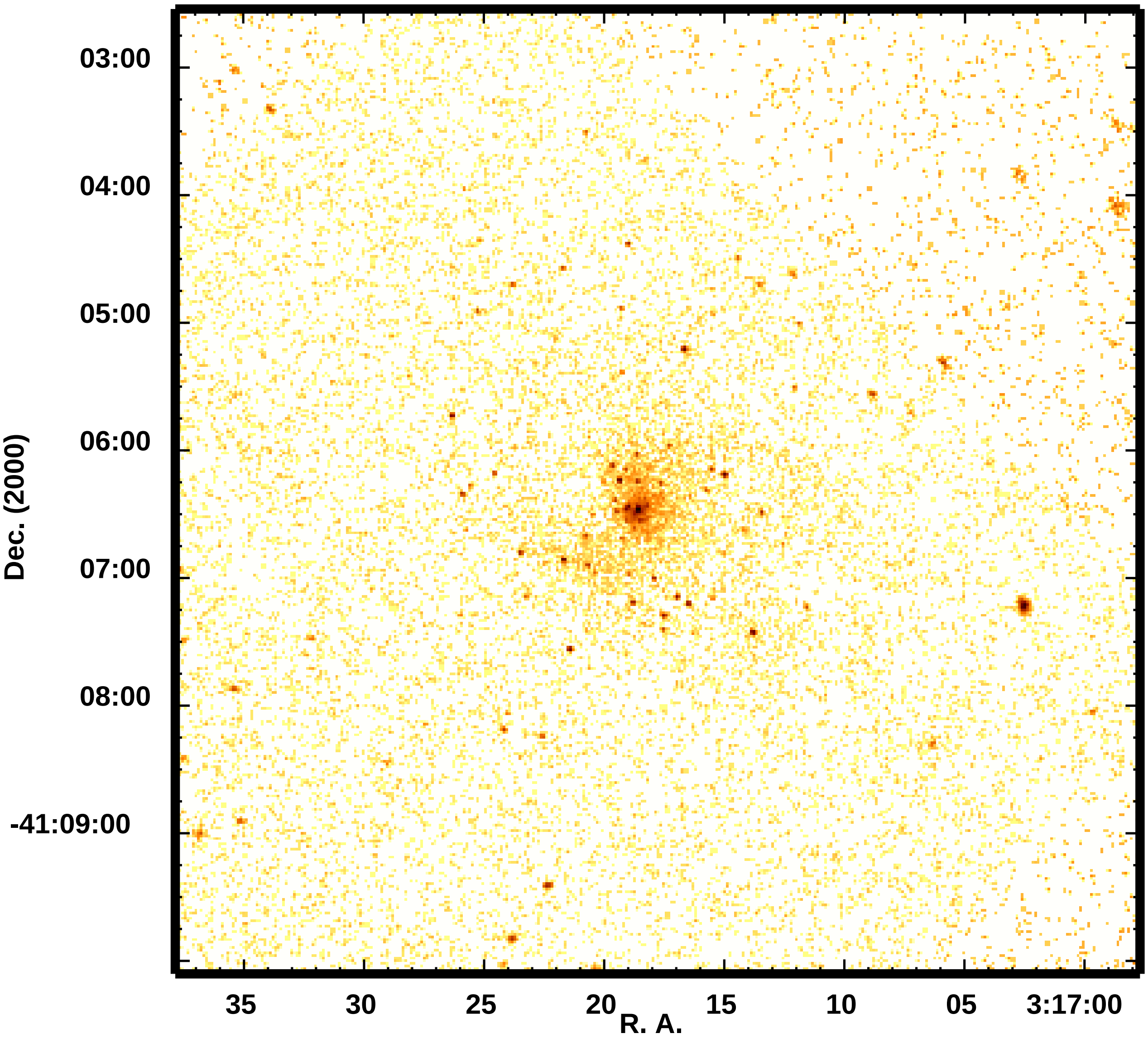
$4' \times 4'$ *Chandra* ACIS-S image of the elliptical galaxy NGC 4697 (Sarazin et al. 2000).



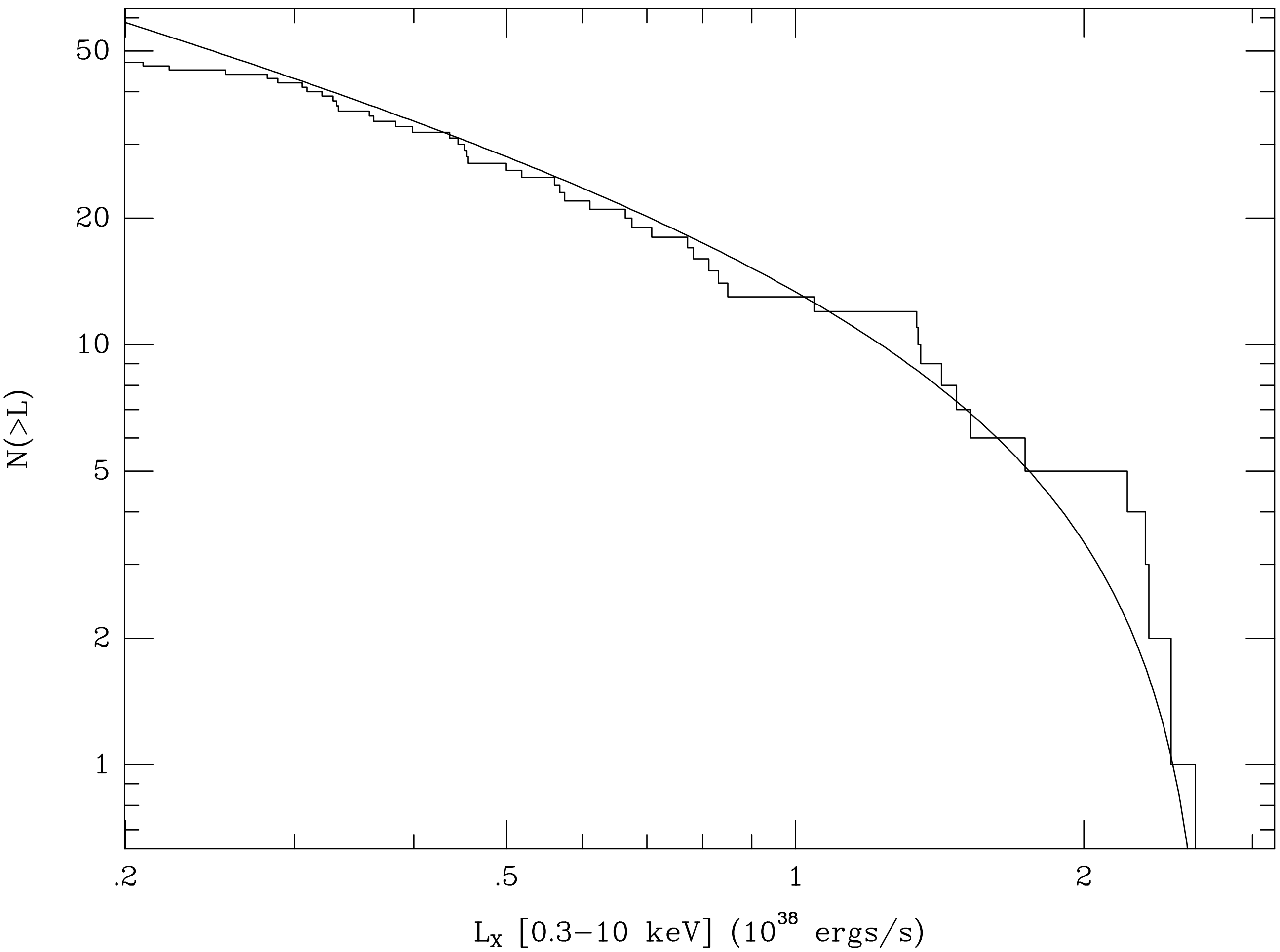
Luminosity function of 90 X-ray point sources found within NGC 4697. There is a break in the luminosity function at 3.2×10^{38} ergs s^{-1}, the approximate Eddington luminosity of a 1.4 $M_\odot$ accreting neutron star.



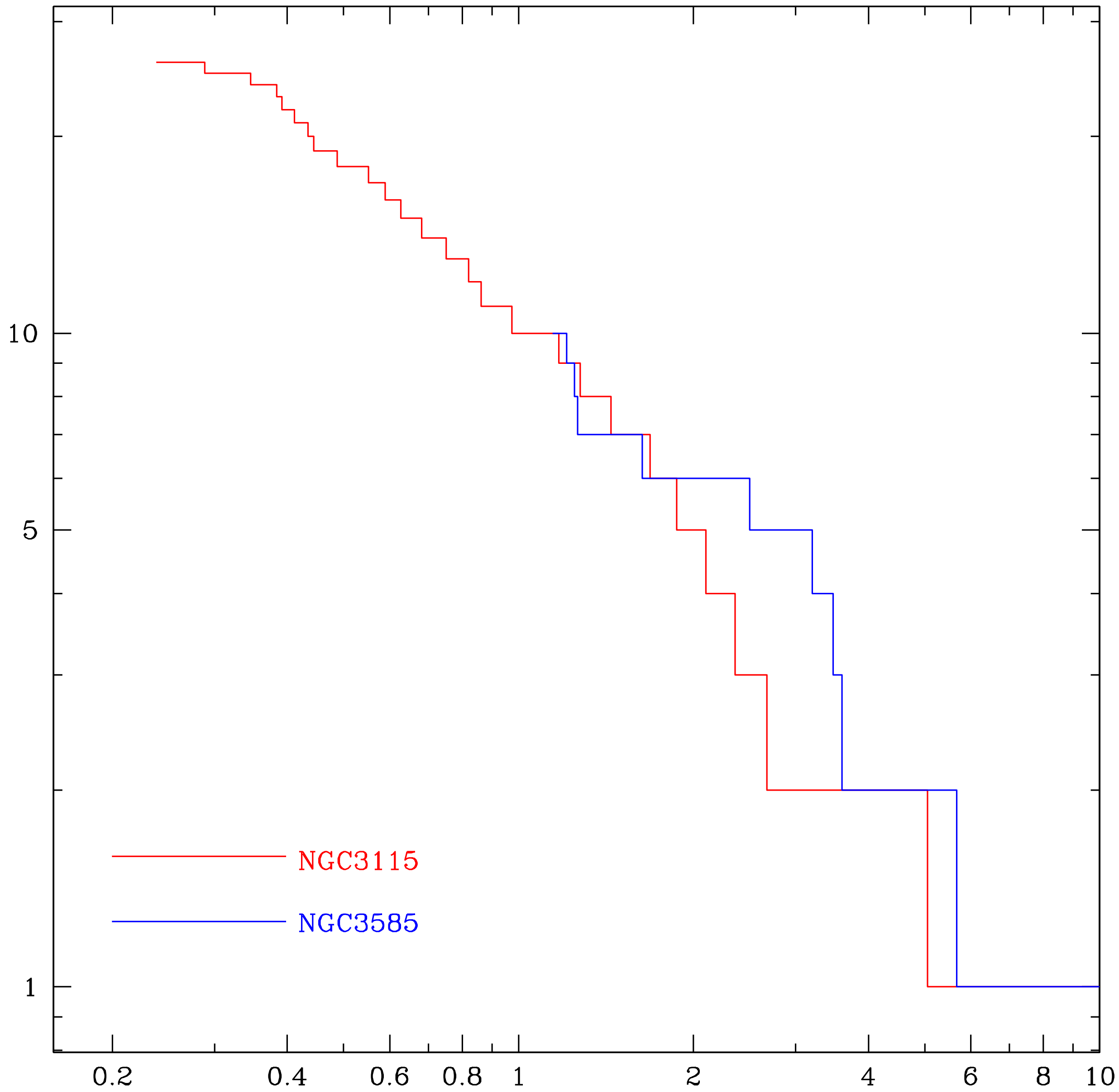
Luminosity function of X-ray point sources found within NGC 1553. There is a similar break in the luminosity function at 4.1×10^{38} ergs s^{-1}.



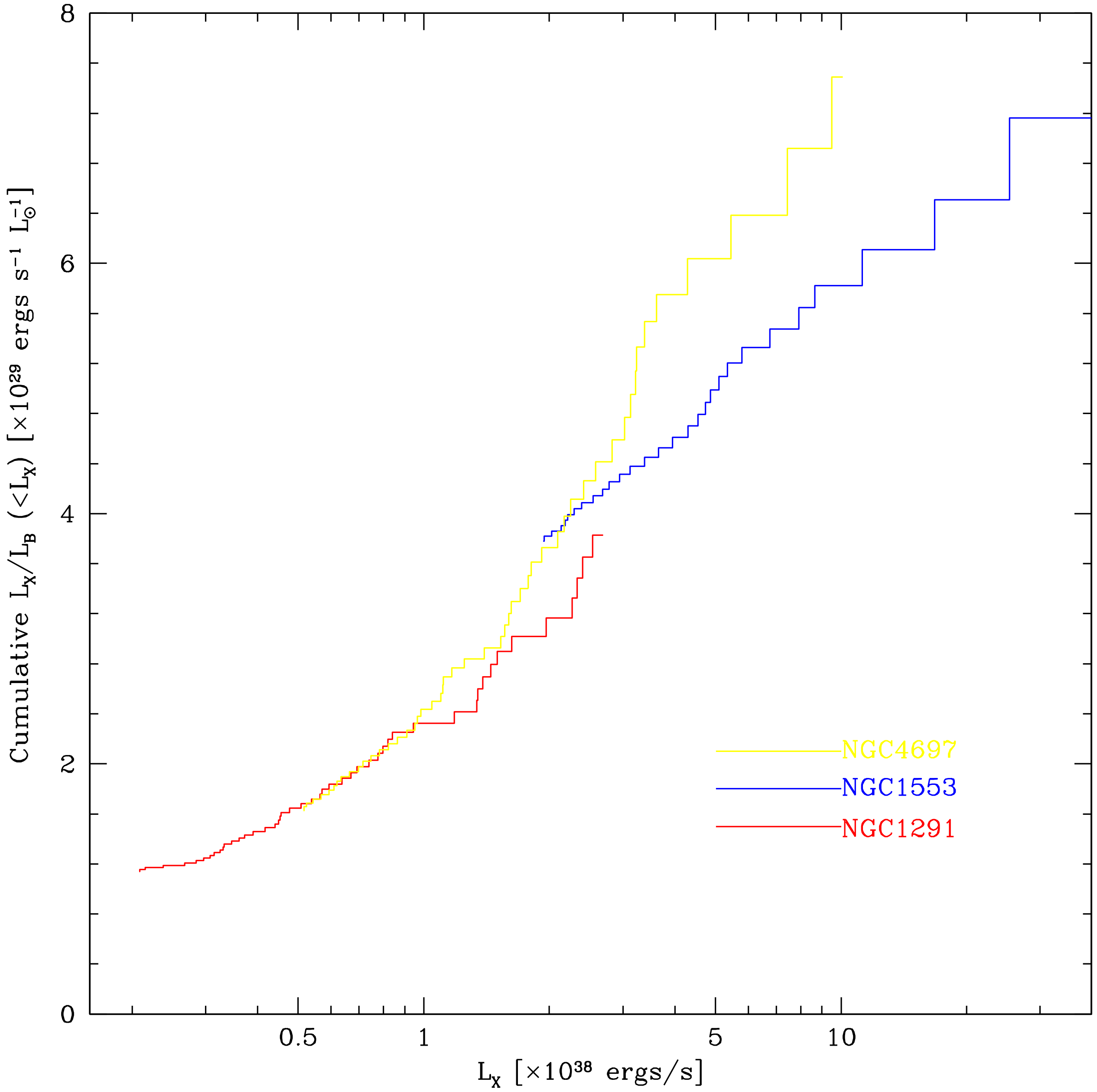
$4' \times 4'$ *Chandra* ACIS-S image of the Sa galaxy NGC 1291 (Irwin et al. 2001).



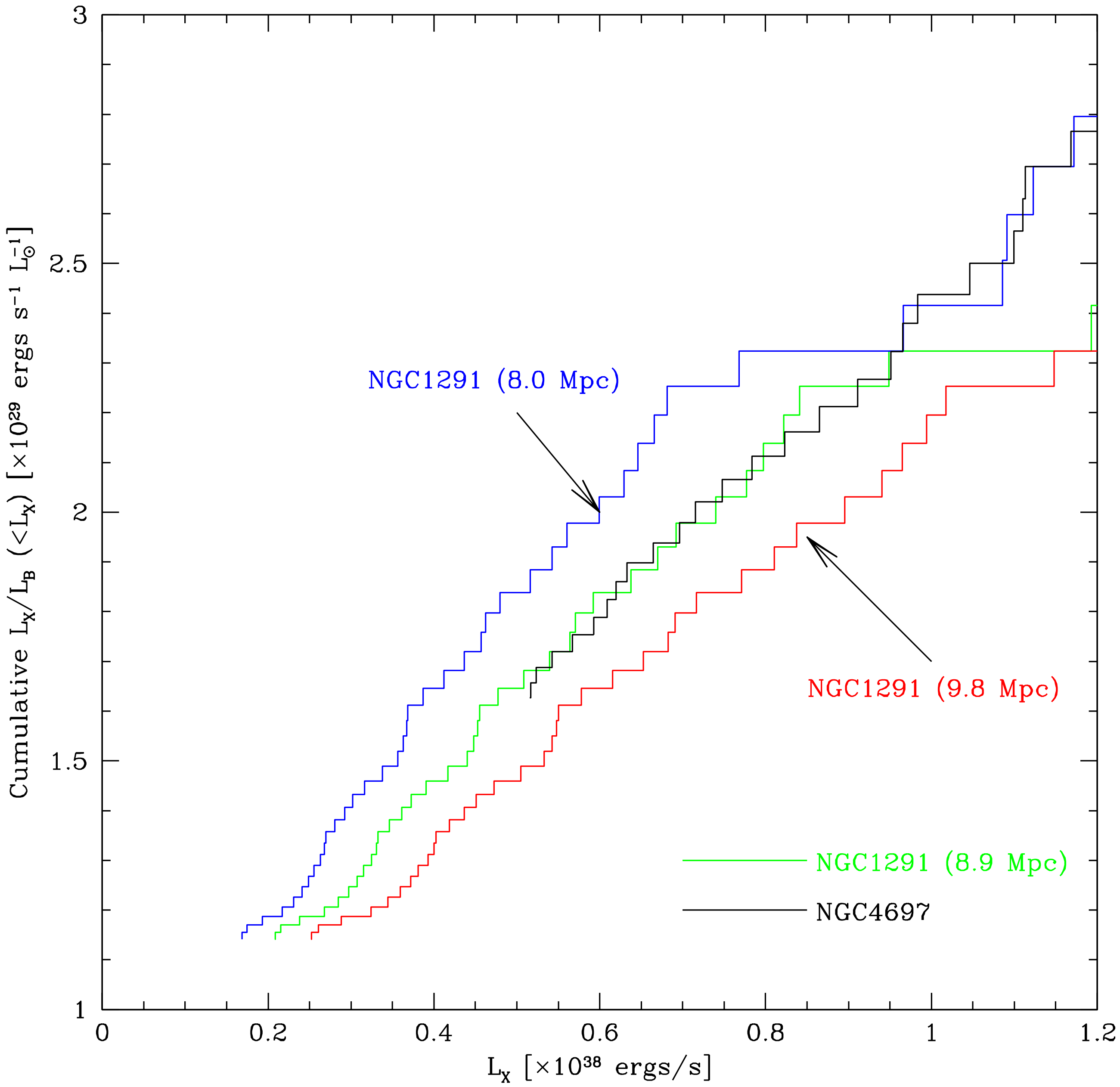
Luminosity function of X-ray point sources found within NGC 1291. Here, there is a cut-off rather than a break at $\sim 3 \times 10^{38}$ ergs s^{-1}.



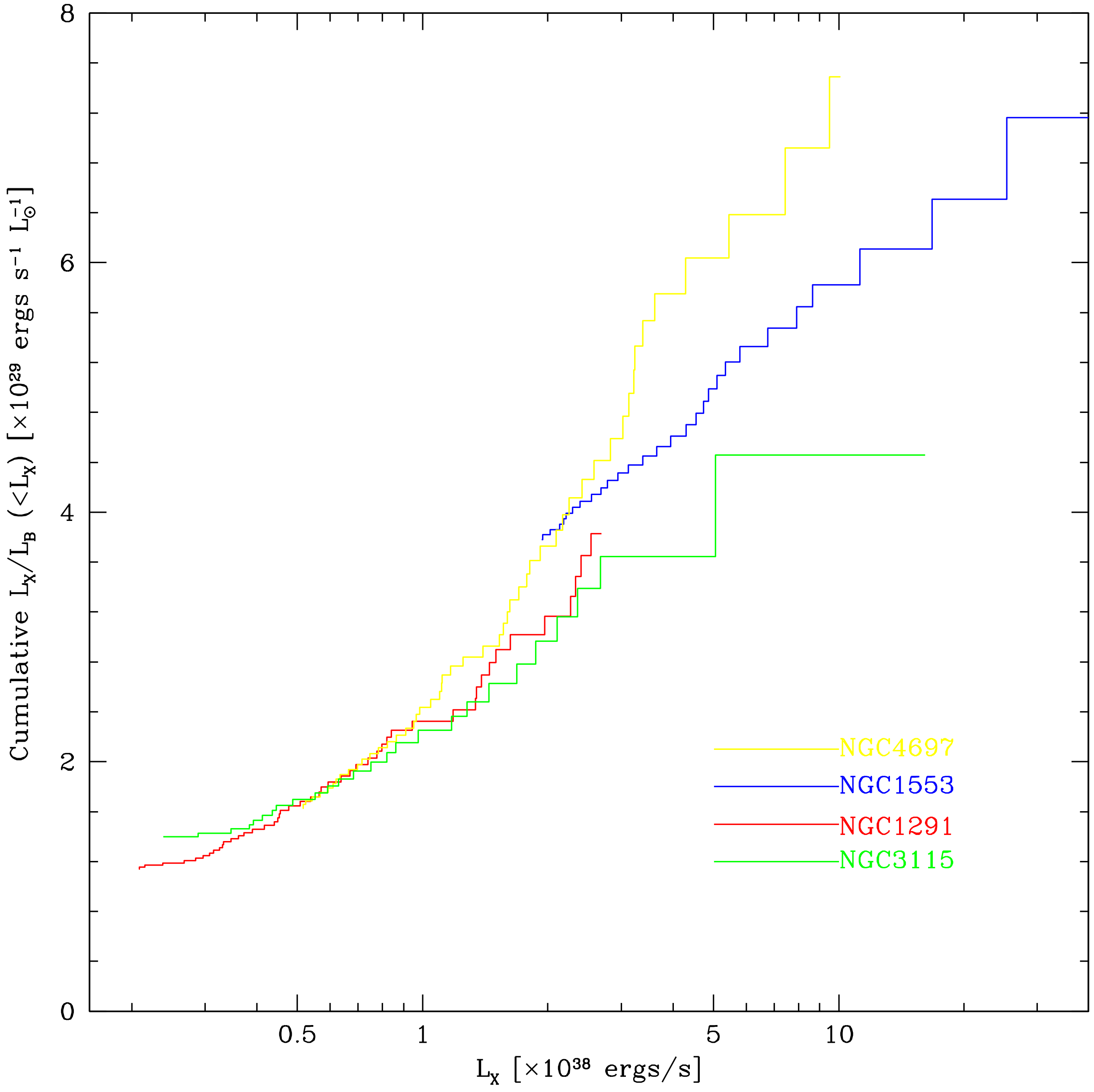
Luminosity functions of X-ray point sources found within NGC 3115 and NGC 3585.



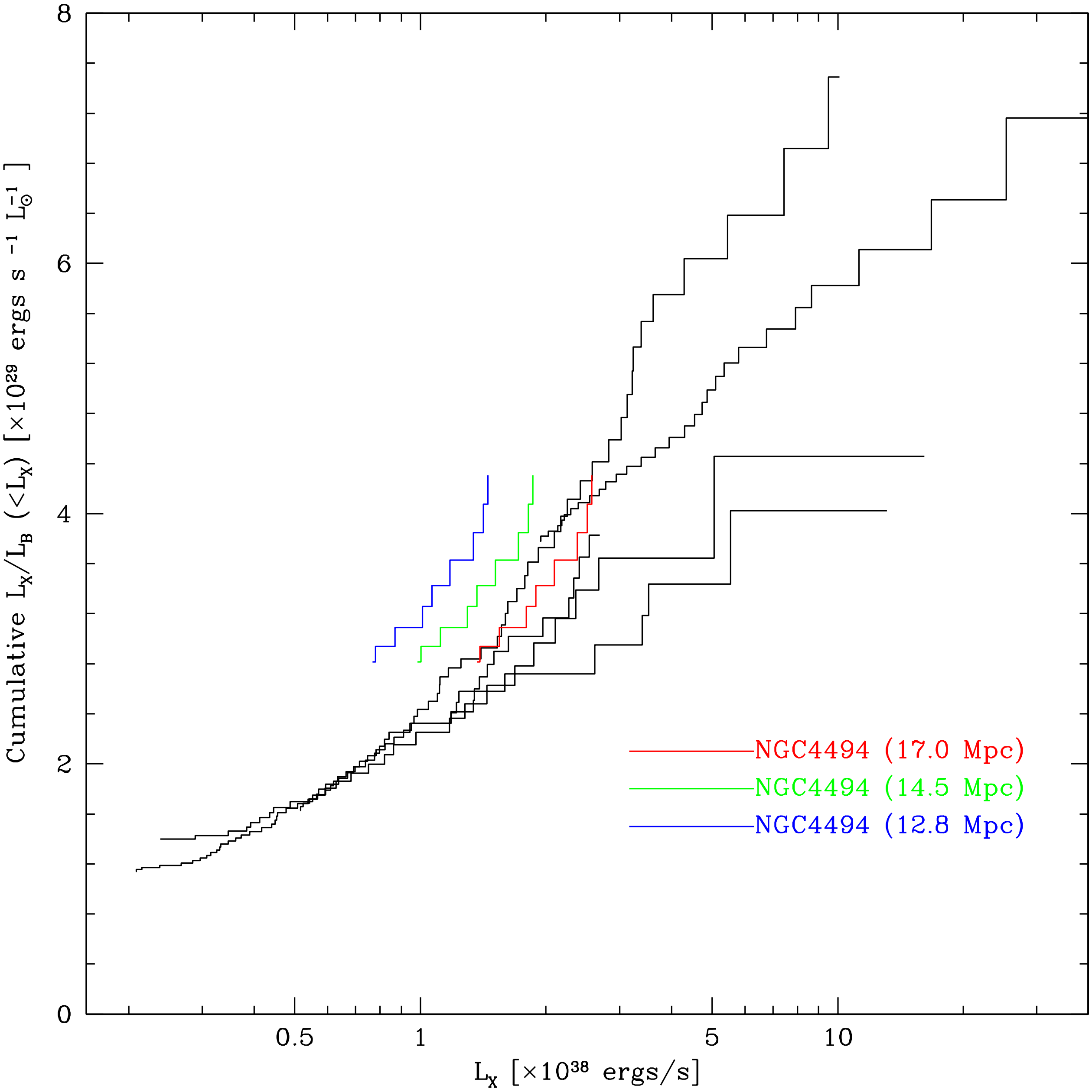
Cumulative L_X/L_B profiles for four galaxies. Above 10^{38} ergs s^{-1} there is considerable spread in the number and integrated luminosity of sources within galaxies, but below 10^{38} ergs s^{-1} there is remarkable agreement.



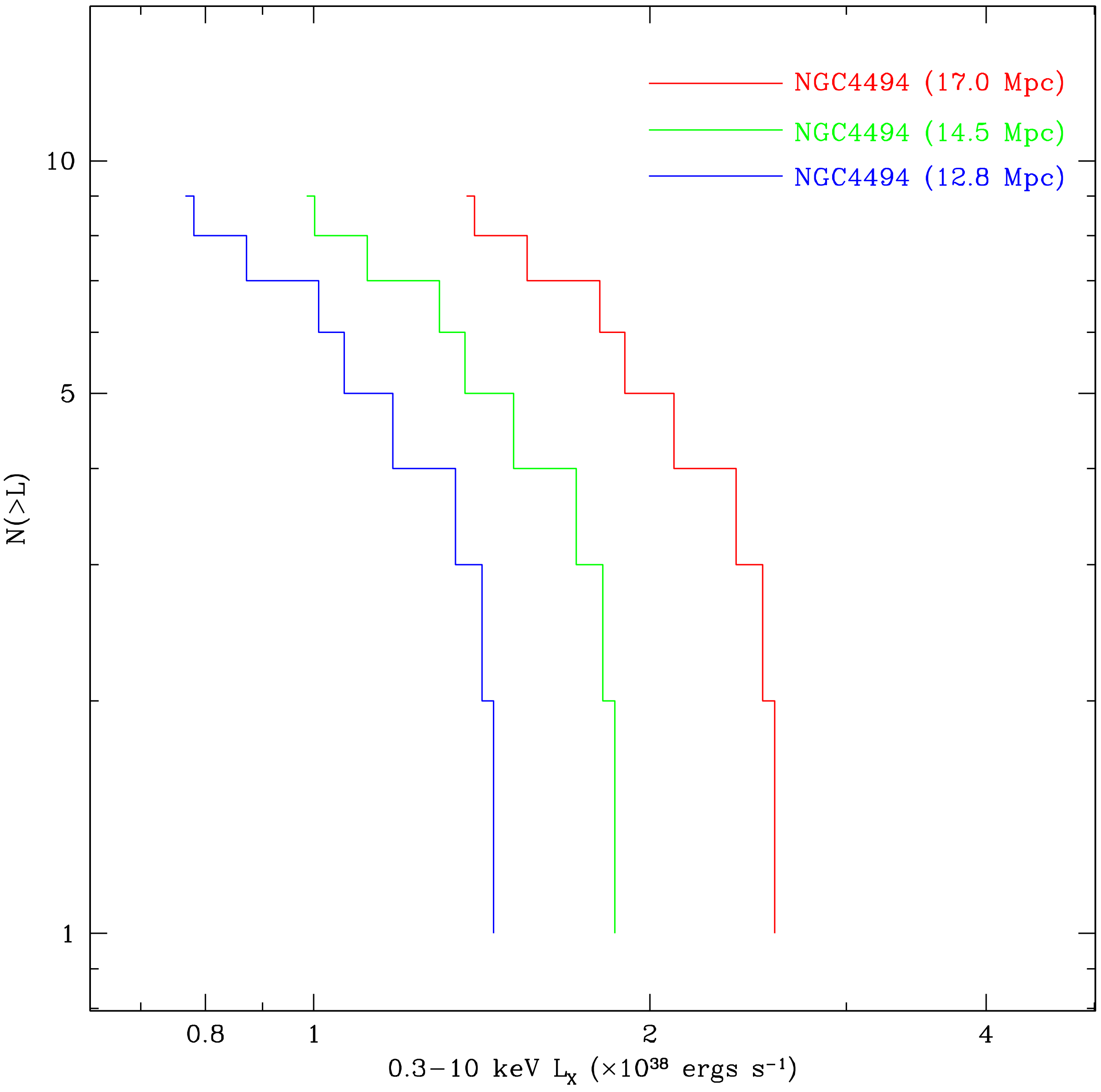
A zoom-in of the lower left corner of the last figure, showing how changing the assumed distance changes the cumulative L_X/L_B profiles. This line-up of the cumulative L_X/L_B profiles might be used as a distance indicator to nearby galaxies.



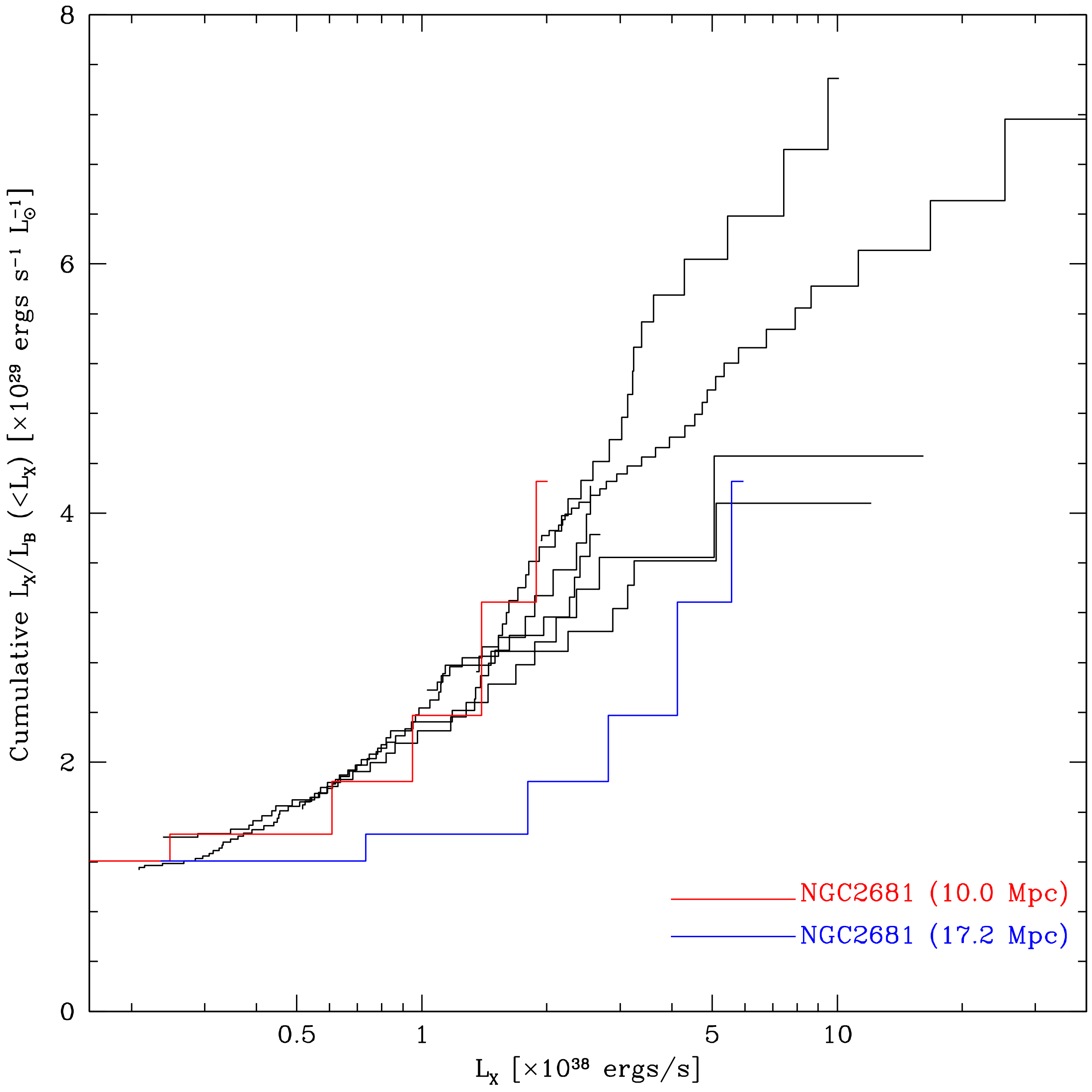
The cumulative L_X/L_B profile of NGC 3115 agrees quite well with those of NGC 1291 and NGC 4697 at luminosities below 10^{38} ergs s^{-1}.



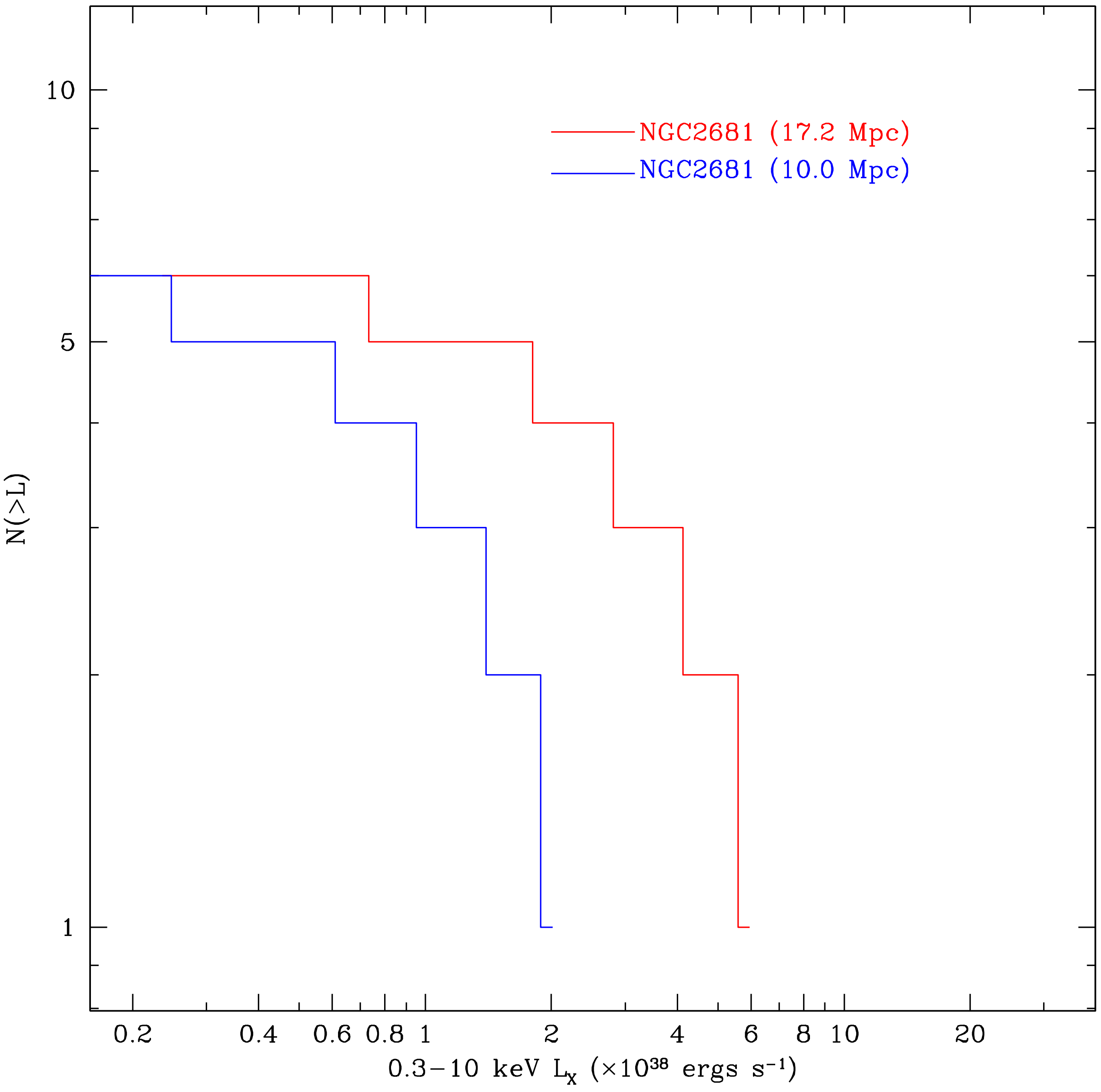
Cumulative L_X/L_B profiles for NGC 4494 assuming three different distances taken from the literature. The largest value of the distance (17.0 Mpc) gives a cumulative L_X/L_B profile more in line with the other galaxies.



Luminosity function of X-ray point sources found within NGC 4494 assuming three different distances. Again, a distance of 17.0 Mpc gives a cut-off at a value nearest the Eddington limit of an accreting neutron star.



Cumulative L_X/L_B profiles for NGC 2681 assuming two different distances taken from the literature. A value of 10.0 Mpc is preferred.



Luminosity function of X-ray point sources found within NGC 2681 assuming two different distances. Again, a distance of 10.0 Mpc gives a cut-off at a value nearest the Eddington limit of an accreting neutron star.

Uses and Limitations of Cumulative L_X/L_B Distance Estimator Method

- A true test of this method will come when two galaxies known to be within the same group are tested.

- This method does not set the zero point for a distance scale (unless one uses the break at 3×10^{38} ergs s^{-1}).

- The galaxy must be nearby (within 20 Mpc) to keep Chandra observations $<$ 100 kiloseconds.

- The method will be difficult to use for galaxies with large amounts of hot gas, which hinders the detection of LMXBs.

Conclusions

- The Log N vs. Log L_X relation of LMXBs in early-type systems exhibits a break or cut-off at a luminosity of 3×10^{38} ergs s^{-1}, appromixately the Eddington luminosity of an accreting 1.4 $M_{\odot}$ neutron star (neutron star–black hole transition?).

- There is a considerable spread in the number of sources more luminous than 10^{38} ergs s^{-1} from galaxy to galaxy. Conversely, there is remarkable agreement in the number and cumulative luminosity of sources in each galaxy below 10^{38} ergs s^{-1} once normalized by the optical luminosity of the galaxy.

- This agreement at lower luminosities could indicate that the high end of the initial mass function was very similar in early-type galaxies before the high mass stars evolved off the main sequence.

- The break (cut-off) luminosity coupled with the cumulative L_X/L_B curve might be a useful distance estimator to nearby galaxies, one of the very few non–optical methods currently available.