Implications of the Observed

Ultraluminous X-ray Source Luminosity Function

Douglas A. Swartz¹, Allyn Tennant², Roberto Soria³, Mihoko Yukita⁴

¹Universities Space Research Association, NASA/MSFC ²Space Science Office, NASA/MSFC ³Curtin Institute of Radio Astronomy ⁴Department of Physics & Astronomy, University of Alabama Tuscaloosa

We present the X-ray luminosity function (XLF) of ultraluminous X-ray (ULX) sources with 0.3-10.0 keV luminosities in excess of 10^39 erg/s in a complete sample of nearby galaxies. The XLF shows a break or cut-off at high luminosities that deviates from its pure power law distribution at lower luminosities. The cut-off is at roughly the Eddington luminosity for a 90-140 M☉ accretor. We examine the effects on the observed XLF of sample biases, of small-number statistics (at the high luminosity end) and of measurement uncertainties. We consider the physical implications of the shape and normalization of the XLF. The XLF is also compared and contrasted to results of other recent surveys.

What are ULXs and Why Study Them?

Ultra-luminous X-ray sources are defined as the most X-ray luminous off-nucleus (non-AGN) point-like objects in nearby galaxies. Their extreme X-ray luminosities are higher than that of stellar-mass black holes, typically >10^39 erg/s. Thus, ULXs are potentially beacons of intermediate-mass black holes lying somewhere between stellar-mass black holes and supermassive galactic nuclei. Alternatively, ULXs may be mildly super-Eddington sources powered by more modest mass accretors but with high mass accretion rates, mass outflows, and thick accretion disks (see Feng & Soria 2011 for a recent review). Regardless, ULXs remain among the most extreme and enigmatic objects known.

How was the Sample Chosen?

Our aim was to produce a statistically rigorous sample of ULXs by using a well-defined sample of nearby galaxies. We began with all galaxies within 14.5 Mpc in the Uppsala Galaxy Catalog (UGC) that meet its completeness limit m₀ = 14.5 mag. The UGC (Nilson 1973) contains all galaxies north of B1950 6 = -2-36° in both of two complete samples: galaxies with angular diameters >1 on the first POSS blue prints and galaxies brighter than photographic magnitude m₀ = 14.5 mag in the Zwicky Catalog of Galaxies and Clusters of Galaxies. This resulted in a sample of 266 galaxies. We then eliminated those galaxies below the completeness limit of the Infrared Astronomical Satellite (IRAS) survey, -1.5 Jy at 60 μm (Beichman et al. 1988). The final sample consists of 127 galaxies and covers 6100 Mpc³.

What are the Main Results?

One hundred seven ULXs were identified in the sample galaxies (see Swartz 2011 for complete details). The luminosity distribution is shown in the right-hand column. ULXs are detected in this sample at rates of one per 3.2×10^5 M☉, one per 0.5 Ms, yr⁻¹ star formation rate and one per 57 Mpc³, corresponding to a luminosity density of 2×10^37 erg s⁻¹ Mpc⁻³ or about 10% of the AGN X-ray luminosity density in the current epoch. At these rates we estimate as many as 19 additional ULXs remain undetected in fainter dwarf galaxies within our survey volume. An estimated 14 objects, or 13%, of the 107 ULX candidates are expected to be background sources.

Sample Biases

Dwarf Galaxies: Our selection criteria omits most dwarf galaxies as shown by the mass distribution of our sample galaxies (solid histogram) compared to the Local Volume. But the numbers of ULXs are known to correlate with galaxy-wide star formation rate in spirals (indicating a HMXB contribution) and with galaxy mass in ellipticals (from the LMXB population). Dwarf galaxies account for 85% of (indicating a HMXB contribution) and with galaxy mass in ellipticals are known to correlate with galaxy-wide star formation rate in spirals.

Implications of the Observed XLF

- The observed cutoff luminosity or break in the XLF implies an upper limit to the mass of the ULX accretor which is similar to the theoretical upper limit that can be obtained for black holes from single star evolution in the current epoch. This suggests that the vast majority of ULXs represent the extreme end of the normal X-ray binary population.
- The rather flat slope of the observed XLF means that the X-ray luminosity of a normal (non-AGN) galaxy is dominated by the most luminous X-ray point sources.
- The overall normalization of the observed XLF and the luminosity density of ULXs implies that ULXs account for roughly 5% of the cosmic X-ray background. With 80-90% resolved into AGN and QSOs, this leaves as little as 5% of the X-ray background unaccounted for.
- The rare ULX with luminosity far above the cutoff luminosity (e.g. Farrell+2009) cannot be accounted for suggesting a new class of object, perhaps the elusive intermediate mass black hole.

References

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