A search for intermediate-mass black holes in the *Swift*-XRT catalog

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1. Abstract

Intermediate-mass black holes (IMBH) are thought to be the building blocks of supermassive black holes that are found at the center of massive galaxies, but evidence for their existence is elusive. We performed a search for IMBH in *Swift*-XRT data by studying hyperluminous X-ray source candidates (HLX), which were identified through a cross-correlation of the *Swift*-XRT catalog with the Galaxy List for the Advanced Detector Era (GLADE [1]) covering nearly 2 million galaxies with high completeness up to 300 Mpc. This selection contains foreground stars and background AGN that we partly eliminate by developing a classification into 3 classes (AGN, star and stellar-mass compact objects (CO)) based on the source properties. Thanks to this classification we are able to obtain 110 HLX candidates including 5 HLX previously identified in the literature. We are currently validating the nature of these objects.

2. Introduction

Supermassive black holes, in particular those as massive as $10^9 M_\odot$ that we observe at redshift $z > 6$ (e.g. [2]), are likely to be formed by mergers of intermediate-mass black holes (IMBH, $10^2 < M_{BH} < 10^5 M_\odot$) [3]. Indeed the Eddington limit does not allow a sufficient accretion rate to form them starting from stellar-mass seeds. IMBH may have formed e.g. by gravitational collapse of the population III, very massive stars, or by collision of stars in globular clusters [3]. Several methods have been developed to search for them, notably by studying hyperluminous X-ray sources (HLX, $L_X > 10^{41}$ erg/s, implying $M_{BH} > 100 M_\odot$ according to the Eddington limit) located outside the nucleus of their host galaxy. With its nearly uniform sky coverage and high flux sensitivity, *Swift* is particularly well-suited to carry out a search for new HLX candidates. Its catalog of X-ray sources [4] contains 151524 sources compiled from 2.5 million observations.

3. HLX selection

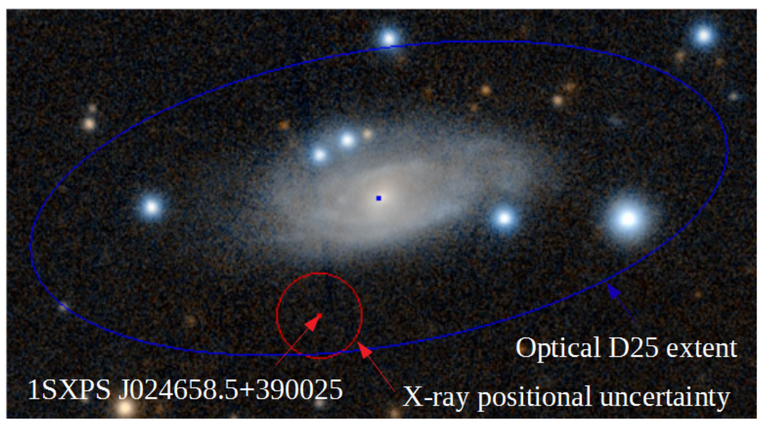

Figure 1: Offnuclear X-ray source overlapping UGC 2243
Background: PanSTARRS DR1 color (g,z bands)

Using TOPCAT we retrieved 6212 X-ray sources whose error circle overlap with a galaxy from GLADE (represented by an ellipse whose semi-major axis is D_{25}, at the isophotal level 25mag/arcsec^2 in the B-band), including 2887 sources outside the nucleus. We computed their observed peak X-ray luminosity in the band 0.3−10 keV using the distance of the galaxy and obtained 506 HLX candidates as a result. However this sample is contaminated by foreground stars and background AGN (Figure 2). We thus classified sources as star, AGN or stellar-mass compact object (CO) using their X-ray, optical and infrared properties provided by *Swift* and the counterparts in USNO-B1 and 2MASS, plus their location and variability.

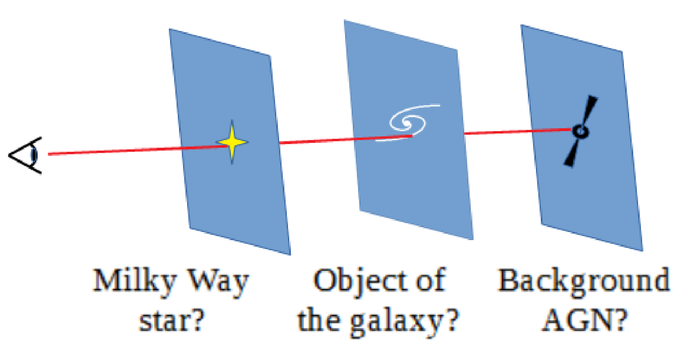

Figure 2: Nature of HLX candidates

4. Classification of X-ray sources

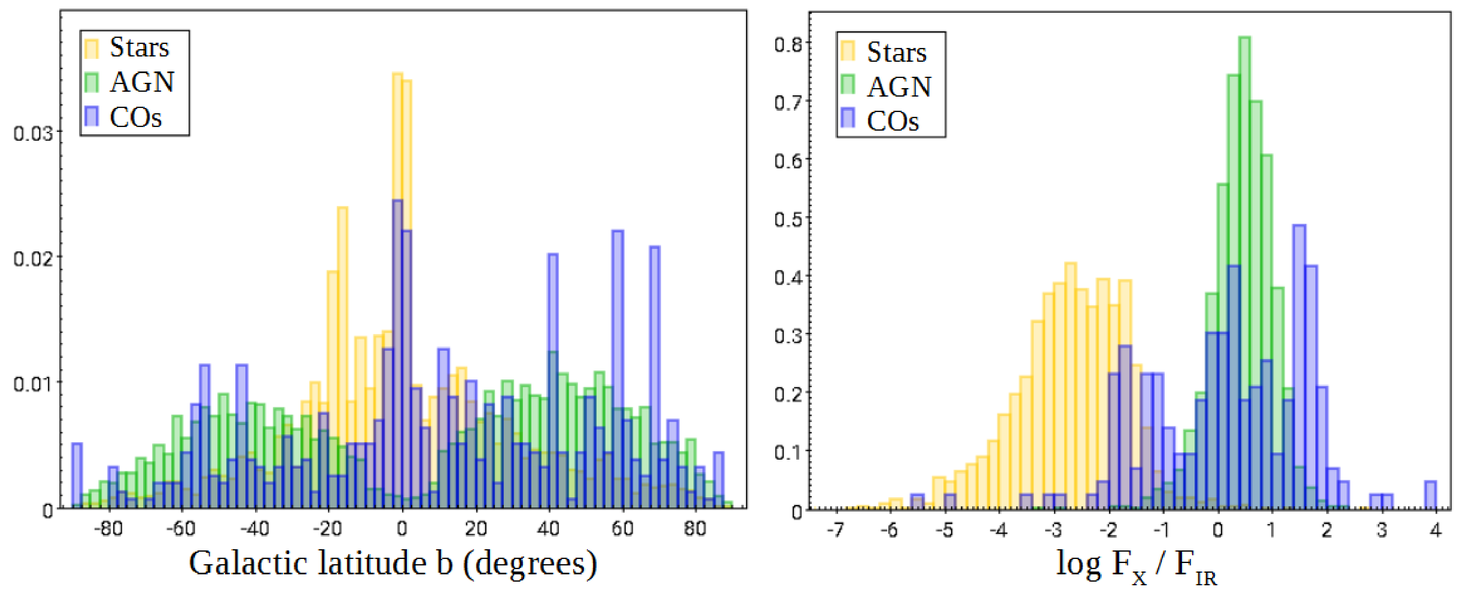

Figure 3: Normalized distributions of two properties for each class of the reference sample

We built a reference sample of 25817 known sources, i.e. whose position is compatible with a known AGN (80% of the sample), star (17%) or CO (3%). As shown in Figure 3 we thus obtained the distributions of properties such as the galactic latitude, the X-ray to infrared flux ratio, the hardness ratios and different variability measurements for stars, AGN and COs. The sources are classified as follow: the distributions of Figure 3 are treated as probability distribution functions. The likelihood of each class is then computed for each source, as a weighted product of the PDF values for each property:

$$\mathcal{L}(\mathrm{AGN}) = \mathcal{L}(\mathrm{AGN} \mid p_1)^{\alpha_1} \times \mathcal{L}(\mathrm{AGN} \mid p_2)^{\alpha_2} \times ... \times \mathcal{L}(\mathrm{AGN} \mid p_n)^{\alpha_n}$$

where $p_1 ... p_n$ refer to the properties of the source and $\alpha_1 ... \alpha_n$ are inferred by a Monte-Carlo method optimizing the classification of COs in the reference sample. The attributed class is the one giving the highest likelikood.

5. Results

The recall rates of the classification are 93%, 96% and 65% for AGN, stars and COs of the reference sample respectively, and the false positive rates are 7%, 1% and 40%. However when applied to the whole catalog the classification returns 24% of COs and 8% of stars, which is not what is expected from a catalog of X-ray sources.

A first attempt at cleaning up the HLX sample gives 10 stars and 386 AGN, leaving 110 HLX candidates. They include HLX-1 [5] which is one of the most reliable IMBH candidates, and 4 other candidates previously identified in the literature [6] [7] [8]. The nature of the remaining candidates is currently under study.

6. Conclusion and future work

- *Swift* X-ray sources can be classified with reasonable accuracy using their spatial, spectral and timing properties
- This classification can help to decontaminate HLX candidates and thus to discover new IMBH
- We obtained 110 HLX candidates including 5 already known in the literature, while the others need to be validated individually, e.g. using spectral modelling
- Further work is desirable to improve the classification method, e.g. using machine learning

7. References

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