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V2-CEMN: IDENTIFICATION OF ASTROPHYSICAL X-RAY SOURCES

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Abstract. During the 2022-2023 academic year, the group V2-CEMN of the participative astronomy course at IPSA worked in collaboration with a high-energy astronomer, helping him on the development and scientific exploitation of a citizen science experiment, CLAXSON. CLAXSON is a website on which people classify a variety of astrophysical X-ray sources. Thanks to the *XMM-Newton* space observatory, more than 13000 observations have been collected and transformed into catalogues. CLAXSON uses these data and multiwavelength archival data for the users to classify sources. The main goal of this website is to categorise as much objects as possible to map the sky and to find some interesting objects such as ultraluminous X-ray sources and supermassive black holes in different environments, which can help understand the formation and growth of supermassive black holes. During this year, our group has worked on different aspects of the website. We realised a new tutorial for novice users, contributed to develop and validate an upgrade of the experiment consisting in the classification of ultraluminous X-ray sources, improved the visibility of the website by realising a presentation video and discussed about the new features to add to CLAXSON.

Keywords: Participative astronomy, CLAXSON, high-energy, X-ray binaries, black holes, classification

1 Introduction

Supermassive black holes ($M_{\rm BH} > 10^5 M_\odot$) are ubiquitously found in massive galaxies and contribute to the formation and evolution of galaxies in general, yet their formation and growth is still a largely open question (e.g. Volonteri 2010; Volonteri et al. 2021). They could have been formed by sustained episodes of super-Eddington accretion onto massive seeds, a phenomenon which has its local analogue in ultraluminous X-ray sources (e.g. Gladstone et al. 2009; Kaaret et al. 2017), or by the mergers of these seeds. Some scenarios hence imply the existence of intermediate-mass black holes ($10^2 M_\odot < M_{\rm BH} < 10^5 M_\odot$), which however remain exclusive in current observations with the exception of a few strong candidates detected through their emission in different wavelengths or in gravitational waves (e.g. Farrell et al. 2009; Lin et al. 2018; Chilingarian et al. 2018; Abbott et al. 2020). The advent of deep and large X-ray surveys such as the *XMM-Newton* catalogues (Jansen et al. 2001; Webb et al. 2020) recently opened new avenues to better collect, identify and analyse black holes over their entire mass range. This paper presents the participating astronomy website CLAXSON*, its purpose and how to use it. We then discuss about the V2-CEMN contribution to this website.

2 The website

On CLAXSON, everyone is able to learn how to categorise sources detected in X-rays. Three classes of sources are considered, namely Active Galactic Nucleus (AGN), stars and X-ray binaries. Categorising sources is necessary to accurately map the sky and provide training samples of known sources to feed automatic classification algorithms. More than a hundred thousand sources have been classified on the site, including two thousands by the V2-CEMN group. To classify a source, many parameters have to be considered (Figure 1) such as LoXO, LoXI and Galactic latitude. They respectively refer to the ratios between X-ray and optical or infrared fluxes of the source and the angle it describes with the Galactic plane. Snapshots are also provided to visualise the source in different wavelengths, allowing to classify sources at first sight. Finally, two graphics are shown†, namely the X-ray spectrum and light curve of the source. They are used to recognise various spectral shapes and variability behaviours.

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*`https://xmm-ssc.irap.omp.eu/claxson`
†Some information might be missing for some sources, however snapshots are generally sufficient to classify them.

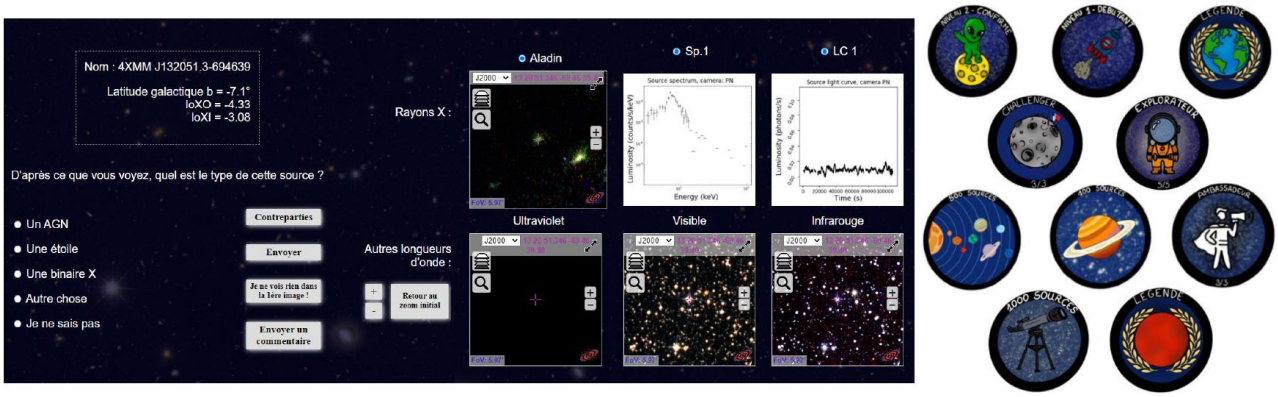

Fig. 1. Left: CLAXSON classification page. **Right:** The badges made by the V2-CEMN group.

3 Our contribution

Concerning our contribution to the website, we made an interactive tutorial for beginners. The purpose of this tutorial is to help beginners to understand the basics of classification and to start classifying. There are two versions of it, a long tutorial explaining the physics behind each parameter used to classify, and a shortened version focusing on the classification task. We also contributed to develop an upgrade of the website to include ultraluminous X-ray sources and our classifications were used to validate it. Some bugs of the website were also fixed in the process. We brainstormed about features to add to the site, such as awarded to users (increasing the gamification of the website) as shown in Figure 1. Finally, we have improved the visibility of the website by presenting it in a video format[‡].

4 Conclusion and outlook

To conclude, we have worked during the 2022-2023 academic year on the improvement of a participating astronomy website, named CLAXSON. The work we provided helped the research of Dr. Tranin. Over the last few years, such citizen science projects have been increasingly acknowledged as a great help to researchers, as illustrated by the success of other platforms such as Zooniverse[§]. The future is bright for CLAXSON: with more than 100,000 classifications and almost 500 sources classified by at least 15 users, the project is entering its scientific exploitation phase and a variety of subprojects are under development to focus on specific categories of X-ray sources. This goes hand in hand with continuous improvements in website features to have more users and enhance their experience.

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[§]https://www.zooniverse.org/