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The search for galaxy cluster members with deep learning of panchromatic HST

imaging and extensive spectroscopy.

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ADC\_Keywords: Clusters, galaxy ; Positional data

Keywords: Galaxy: general - galaxies: photometry -

galaxies: distances and redshifts - techniques: image processing

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methods: data analysis

#### Abstract:

The next generation of extensive and data-intensive surveys are bound to produce a vast amount of data, which can be efficiently dealt with using machine-learning and deep-learning methods to explore possible correlations within the multi-dimensional parameter space.

We explore the classification capabilities of convolution neural networks (CNNs) to identify galaxy cluster members (CLMs) by using Hubble Space Telescope (HST) images of fifteen galaxy clusters at redshift  $0.19 < z < 0.60$ , observed as part of the CLASH and Hubble Frontier Field programmes.

We used extensive spectroscopic information, based on the CLASH-VLT VIMOS programme combined with MUSE observations, to define the knowledge base. We performed various tests to quantify how well CNNs can identify cluster members on the basis of imaging information only. Furthermore, we investigated the CNN capability to predict source memberships outside the training coverage, in particular, by identifying CLMs at the faint end of the magnitude distributions.

We find that the CNNs achieve a purity-completeness rate  $> \sim 90\%$ , demonstrating stable behaviour across the luminosity and colour of cluster galaxies, along with a remarkable generalisation capability with respect to cluster redshifts. We concluded that if extensive spectroscopic information is available as a training base, the proposed approach is a valid alternative to catalogue-based methods because it has the advantage of avoiding photometric measurements, which are particularly challenging and time-consuming in crowded cluster cores. As a byproduct, we identified 372 photometric cluster members, with  $\text{mag}(F814) < 25$ , to complete the sample of 812 spectroscopic members in four galaxy clusters RX J2248-4431, MACS J0416-2403, MACS J1206-0847 and MACS J1149+2223.

When this technique is applied to the data that are expected to become available from forthcoming surveys, it will be an efficient tool for a variety of studies requiring CLM selection, such as galaxy number densities, luminosity functions, and lensing mass reconstruction.

#### Description:

The catalogue consists of 1184 cluster members, 812 of them are spectroscopically classified, while the remaining sample (372) are

candidate members identified by a Convolutional Neural Network, with a limiting magnitude of 25 AB in F814W filter, and membership probability. Members have been identified in the four galaxy clusters RX J2248.7-4431 (AS 1063), MACS J0416.1-2403, MACS J1206.2-0847, MACS J1149.5+2223.

Objects:

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      RA      (2000)   DE      Designation(s)
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22 48 54.3   -44 31 07      RX J2248.7-4431 = ACO S1063
04 16 08.38  -24 04 20.8     MCS J0416.1-2403 = MCS J0416.1-2403
12 06 12.2   -08 48 02      MCS J1206.2-0847 = MCS J1206.2-0847
11 49 35.8   +22 23 55      MCS J1149.5+2223 = MCS J1149.5+2223
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File Summary:

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File Name      Lrecl  Records  Explanations
-----
ReadMe          80      .      This file
clms.dat        64     1184    Candidate CLMs identified by CNN
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Byte-by-byte Description of file: clms.dat

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Bytes Format Units  Label      Explanations
-----
 1- 18 F18.14 deg   RAdeg      Right Ascension (J2000)
20- 38 F19.15 deg   DEdeg      Declination (J2000)
40- 58 F19.16 ---   prob       Membership probability
                                     (-1: spectroscopic source)
60- 64  A5    ---   FoV       Corresponding cluster Field of View (1)
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Note (1): Fields of View as follows:

- m0416 = MACS J0416.1-2403
- m1149 = MACS J1149.5+2223
- m1206 = MACS J1206.2-0847
- r2248 = RX J2248.7-4431 (AS 1063)

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(End) Giuseppe Angora [Univ. Ferrara], Patricia Vannier [CDS] 25-
Sep-2020

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