Looking at globular clusters in galaxy clusters at redshift 0.4 with JWST

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Introduction

The *James–Webb Space telescope* (*JWST*) opened the door for the study of globular clusters (GCs) and ultra–compact dwarfs (UCDs) outside the local Universe. We study GCs and UCDs in SMACS J+0723.3−7328 (SMACS 0723), a galaxy cluster at redshift $z = 0.39$. At such distances, GCs appear as faint point sources surrounding the galaxies of the cluster (Faisst et al. 2022).

While the peak of the GC luminosity function (GCLF) cannot be reached in SMACS 0723, we aim to constrain the luminosity function and study the radial distribution of GCs and UCDs, to compare them with their local Universe counterparts. Similar studies in the same redshift range (Harris et al. 2025) have evidenced a redshift evolution of the GCLF.

Data

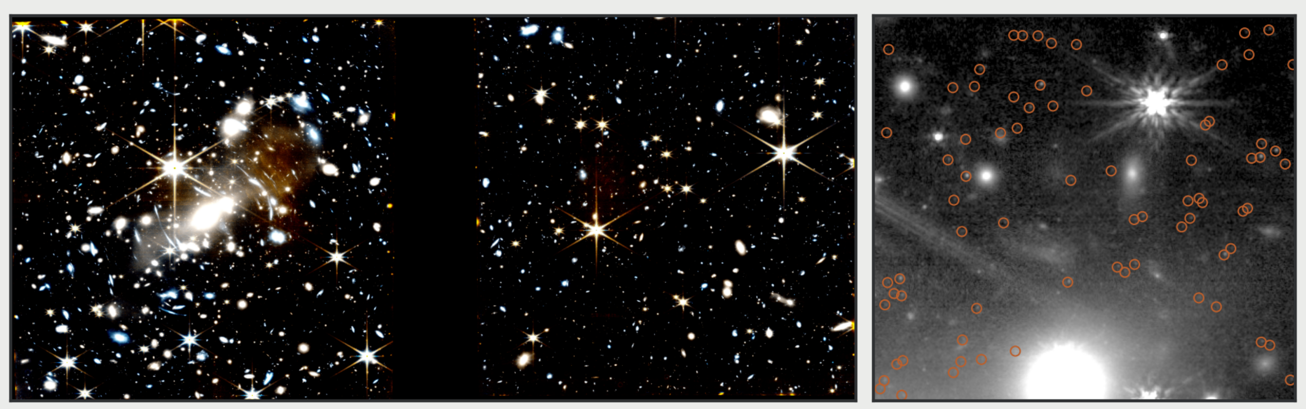

Figure 1: SMACS 0723 galaxy cluster as seen with *JWST* NIRCam. The left panel shows a F200W and F356W colour composition of the whole NIRCam field of view. The right panel is a cutout, in which GCs found in this study are highlighted in orange.

SMACS 0723 was observed with *JWST* Near Infrared Camera (NIRCam) during early-release observations (PID 2736, Fig. 1) The images were obtained through six filters, with the same exposure time of around 7500 s for each filter.

Faisst, A. L., Chary, R. R., Brammer, G., & Toft, S. 2022, ApJ, 941, L11

Harris, W. E., Reina-Campos, M., Keatley, K. E., et al. 2025, ApJ, 993, 210

Voggel, K. T., Seth, A. C., Baumgardt, H., et al. 2019, ApJ, 871, 159

Prediction of the colour–magnitude space of globular clusters

To identify the GCs among the other sources of the field, we generate simulations of their expected magnitude and colours at $z = 0.39$ in JWST bands. For each simulated GC we sample:

- An age from a uniform distribution;
- A metallicity from a uniform distribution;
- A V magnitude from a Gaussian distribution, with variable peak depending on the age of the population.

The variable Gaussian peak accounts for the fading of stellar populations with time due to stellar evolution, meaning that a younger GC distribution is brighter.

Selection of candidate globular clusters

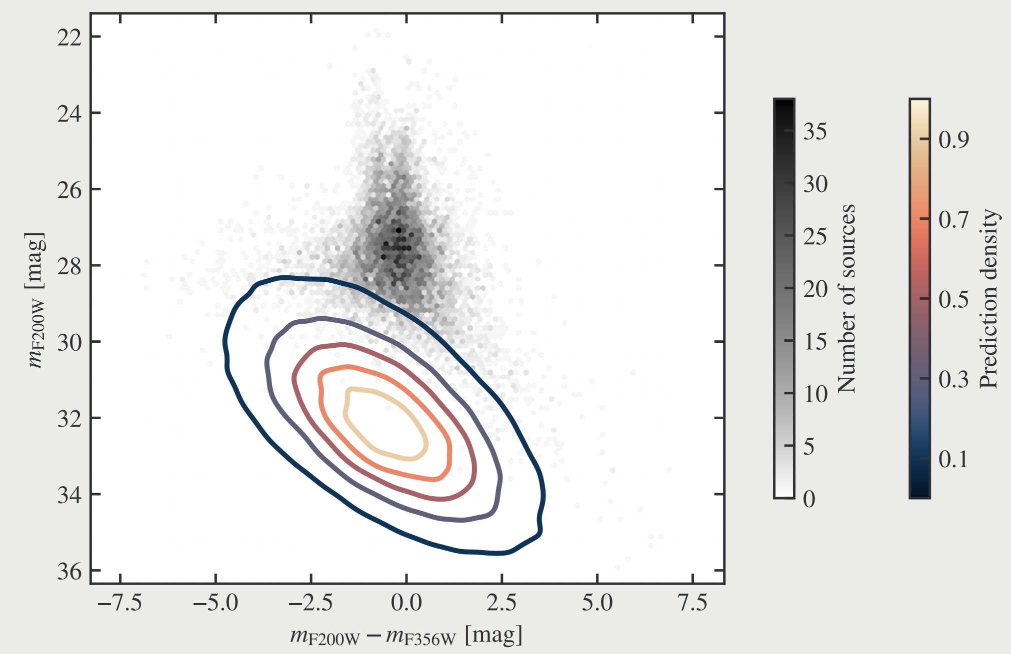

Figure 2: Observed sources (black distribution) and simulated clusters (coloured contours) in the colour–magnitude diagram.

We use `Source-Extractor` and select point sources with a low ellipticity. Then, we use the simulations shown in Fig. 2 to guide our selection of GCs candidates. The final catalogue contains ∼4300 candidate GCs and UCDs in the field, aiming for good purity of the sample.

Radial distribution and luminosity function

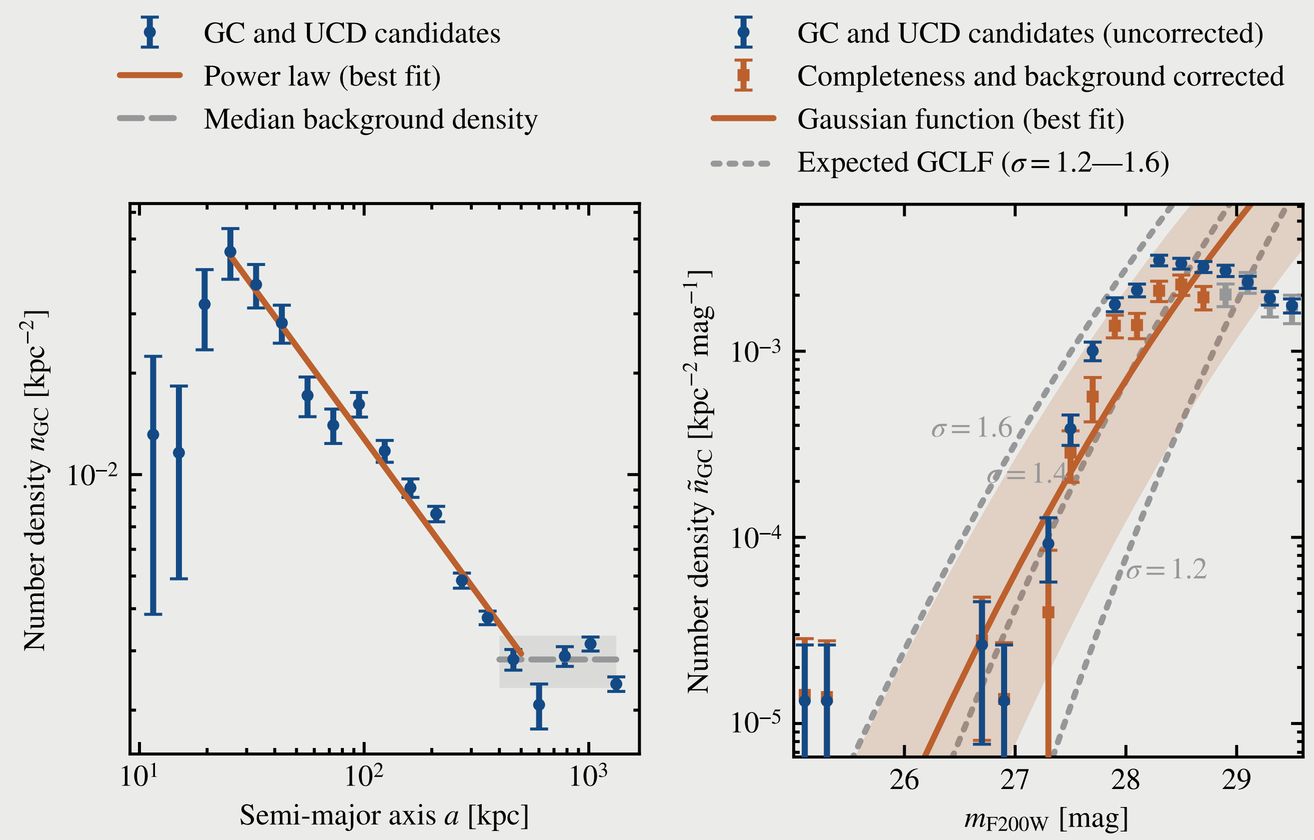

Figure 3: Radial distribution (left panel) and luminosity function (right panel) of GCs and UCDs. The expected GCLF corresponds to a Gaussian distribution with a peak at $m_{F200W} = 33.04$ ($M_V = -7.70$) with a varying standard deviation, and scaled for 10^5 GCs.

We study the radial distribution of GCs and UCDs in elliptical rings to follow the ellipticity of their spatial distribution. We find a power law index $\alpha = -0.91 \pm 0.04$ (Fig. 3), shallower than typical local GCs distributions.

We estimate the GCLF within 500 kpc of the central galaxy (Fig. 3). We correct the distribution for completeness and subtract the background. We observe a flattening close to the 50 % recovery limit, the origin of which is still under investigation. Assuming a Gaussian GCLF that peaks at $m_{F200W,peak} = 33.04$, we find:

- A total number of GCs and UCDs $(3 \pm 2) \times 10^5$
- A standard deviation $\sigma_{F200W} = 1.32 \pm 0.08$

Other GCLF shapes will be examined. Assuming the stripped nuclei fraction from Voggel et al. (2019), we estimate 450 ± 50 stripped nuclei.

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