Data release
Cosmic evolution of the incidence of Active Galactic Nuclei in massive clusters: Simulations versus observations

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Table 1: Overview of the mock catalogue content.

	Name	units	Description
UniverseMachine	id	-	2.1.1
	upid	-	2.1.2
	vmp	km/s (physical)	2.1.3
	v	km/s (physical)	2.1.4
	r	kpc/h (comoving)	2.1.5
	sfr	$M_\odot$/yr	2.1.6
	obs_sfr	$M_\odot$/yr	2.1.7
	lgmp	$\log_{10}(M[M_\odot/h])$	2.1.8
	lgm	$\log_{10}(M[M_\odot/h])$	2.1.9
	lgsm	$\log_{10}(M[M_\odot])$	2.1.10
	lgob_sm	$\log_{10}(M[M_\odot])$	2.1.11
This paper	lgLxGMedian,lgLxAMedian	erg/s	2.2.1
	dist_obs	Mpc/h (comoving)	2.2.2
	x_rot, y_rot, z_obs	Mpc/h (comoving)	2.2.3
	vx_rot, vy_rot, vz_rot	km/s (physical peculiar)	2.2.4
	final_redshift	-	2.2.5
	angle_los	rad	2.2.6
	FOV	rad	2.2.7
	r_parent	kpc/h (physical)	2.2.8
	id_obs	-	2.1.1
	delta_redshift_lim	-	2.2.10
	delta_redshift	-	2.2.11
	lgssfr	$\log_{10}(\mathrm{ssfr}[\mathrm{yr}^{-1}])$	2.2.12
	lgssfr_q_remap	$\log_{10}(\mathrm{ssfr}[\mathrm{yr}^{-1}])$	2.2.13
	SF_Schreiber	-	2.2.14
	[band]_qUM	mag	2.2.15
	[band]_SFRq_remap	mag	2.2.16
	reseed	-	2.2.17
	id_clust_reseed	-	2.2.18

1 Overview

In Muñoz Rodriguez et al. 2022 the role of the environment on AGN triggering is explored. We construct AGN mock catalogues by populating dark matter haloes from MultiDarkPLank2 (MDPL2, Klypin et al., 2016) simulation with galaxies using UniverseMachine (Behroozi et al., 2019). These galaxies are populated with AGN using specific accretion rate distributions derived from observations (Georgakakis et al., 2017; Aird et al., 2018) that describe the probability of a galaxy hosting an accretion event. The explicit assumption of the latter step is that the incidence of AGN in galaxies is independent of environment or halo mass.

Moreover, the observations used to construct the AGN specific accretion rate distributions are mainly from extragalactic survey fields that typically sample intermediate and low density regions of the cosmic web. The model predictions therefore represent the "field" AGN and galaxy population. To study the role of the environment we compare the fraction of AGN predicted by the model with observations of cluster from Martini et al. (2009, 2013).

To make this comparison we implement the observational selection effects onto the simulations. This requires to imitate observations of clusters in the mock catalogues. The N-body simulation boxes are projected onto the sky to generate light cones centered on halos more massive that few times 10^{14}, i.e. similar to the mass of the clusters selected in the observations. Galaxy and AGN membership to the cluster of galaxies follows criteria similar to those adopted in the observations (see Section 3.4 of the paper for more details).

In what follows we detail the content of the dataset of the paper, necessary data to reproduce the results, in concrete Table 2 and Figure 6 of the paper.

2 Dataset

The dataset consist in a collection of light-cones generated for clusters (with typical masses above $10^{14}\,\mathrm{M}_\odot$) at redshifts $z = 0.2, 0.75$ and 1.2. There are 388, 157, 18 unique parent cluster at each of those redshifts. For more details of the selection of these clusters see Section 3.4.1 of the paper. Each of the clusters have been seeded 10 times with AGNs. Due to the stochastic nature of the seeding processes (see Section 3.2 of the paper) this produces 10 different AGN configurations for each cluster. This extended sample has been used to generate Figure 6 and Table 2 of the paper. The catalogues can be accessed through Zenodo[1]. The name of the files correspond to the scaling factor of the Universe at the redshifts cited above.

2.1 UM catalogue

The columns listed below are associated with the UniverseMachine model applied to the MDPL2 N-body simulation. The corresponding catalogues are publicly available at `https://www.peterbehroozi.com/data.html`. The relevant columns are listed below.

2.1.1 id

Unique halo identification number. This number different for each halo in the different simulated boxes in UniverseMachine.

2.1.2 upid

-1 for central halos, otherwise, ID of largest parent halo. This has to main uses: first to isolate centrals (parents) from satellites and construct the parent sample filtering by halo masses; second to study the "true" members of the clusters since satellites haloes have upid equal to the unique identification number of the parent. Note that this "true" members **do not correspond** to the criteria adopted in the paper where follows observational selection effects.

[1] `https://zenodo.org/record/7266395`

2.1.3 vmp

Maximum halo velocity at the time when peak mass was reached (physical km/s). This parameter is not used in our analysis but is included here for completeness.

2.1.4 v

Maximum halo velocity (physical km/s). This parameter is not used in our analysis but is included here for completeness.

2.1.5 r

Halo virial radius as defined in Bryan & Norman (1998) (comoving kpc/h). This value is used to select cluster members. See also Section 2.2.8 below and Section 3.4.3 of the paper.

2.1.6 sfr

Star-formation rate assigned to galaxies by UniverseMachine. This parameter does not include observational systematics. It is not used in our analysis but is included here for completeness.

2.1.7 obs_sfr

Observed star-formation ($M_\odot$/yr) assigned to galaxies by UniverseMachine, including systematics. This is the value used in our analysis to determine apparent magnitudes for individial galaxies following the prescriptiosn of Georgakakis et al. (2020). These magnitudes are relevant for mimicking observation selection effects (i.e. magnitude limits).

2.1.8 lgmp

$\log_{10}$ halo peak historical virial mass ($M_\odot/h$). Virial as defined in Bryan & Norman (1998). This parameter is not used in our analysis but is included here for completeness.

2.1.9 lgm

$\log_{10}$ halo virial mass ($M_\odot/h$). Virial as defined in Bryan & Norman (1998). This value describes the halo mass of the halo at the moment of the snapshot. This value is used as a proxy of velocity dispersion of the cluster. It is relevant to mimic selection effects of observations, see Section 2.2.11 and Section 3.4.3 of the paper for further details.

2.1.10 lgsm

$\log_{10}$ of the stellar mass assigned to the galaxies by UniverseMachine. It does not include systematics and is not directly used in our analysis. It is included here for completeness.

2.1.11 lgobs_sm

$\log_{10}$ observed stellar mass, including random and systematic errors ($M_\odot$). This mass is used to calculate the specific star formation rate of the galaxy. This is relevant on for the calculation of the magnitudes associated to the galaxy and galaxy member selection. See See Section 2.2.15 and 2.2.12, also Section 3.4.3 of the paper for further details.

2.2 Added features

This section contains features that have been added to UniverseMachine catalogues. They are associated with the seeding of galaxies with X-ray AGN and the projection of the simulation boxes onto the sky. they are associated with the seeding of galaxies with X-ray AGN and the projection of the simulation boxes onto the sky.

2.2.1 lgLxGMedian, lgLxAMedian

X-ray luminosity (erg/s) using the Georgakakis et al. (2017) and Aird et al. (2018) specific accretion rate distributions respectively. These values are estimated as $L_X = K \cdot \lambda \cdot M_\star$ where K is a constant, λ is drawn randomly from the specific accretion rate distribution and $M_\star$ correspond to lgobs_sm (see Sec. 2.1.11). See further details in Section 3.2 of the paper.

2.2.2 dist_obs

Comoving distance to the observer in Mpc/h. This is used to calculate the redshifts of the objects which is relevant to the member selection, see Sec. 2.2.5 and Section 3.4.3 of the paper.

2.2.3 x_rot, y_rot, z_obs_rot

Coordinates of the haloes after projecting into the sky-plane. These parameters are not used in our analysis but is included here for completeness.

2.2.4 vx_rot, vy_rot, vz_rot

Velocities of the haloes after projecting into the sky-plane. Used to calculate redshifts of the objects which is relevant to the member selection, see Sec. 2.2.5 and Section 3.4.3 of the paper.

2.2.5 final_redshift

Redshift assigned to the object including the effect of peculiar velocities. This parameter is relevant to the selection of cluster members. See Sec. 2.2.10 and Sec. 2.2.10, also Section 3.4.3 of the paper.

2.2.6 angle_los

Angular separation relative to the centre of the cluster in radians. The parameter is used in combination with the cluster FOV (see Sec. 2.2.7) to determine cluster membership as described in the paper (see Sec. 3.4.2).

2.2.7 FOV

Angle subtended by the virial radius of the parent halo in radians. This is the angular distance that correspond to radius of the parent cluster (r_parent, see Sec 2.2.8) at the redshift of the cluster, i.e $z = 0.2, 0.75$ or 1.25. In combination with angle_los (see Sec. 2.2.6) it is used to estimate cluster membershipas described in the paper (see Sec. 3.4.2).

2.2.8 r_parent

Size of the parent halo in **physical** units in kpc. Physical units are defined as comoving divided by 1+redshift, i.e (r/(1+redshift)), where r is described above (see Sec. 2.1.5) and redshift (z) correspond to the redshift of the cluster, i.e $z = 0.2, 0.75$ or 1.25. The paramere r_parent is used to determine the cluster FOV (see Sec. 2.2.7)

2.2.9 id_obs

Unique identification number of the halo (see Sec. 2.1.1) that corresponds to the cluster being simulated. For a given light-cone this number is the id (see Sec 2.1.1) of the massive cluster that has been projected onto the sky-plane. This number is the same for all the objects within the same light-cone. Note that this number is also the same for different reseeding of the same cluster. Therefore, it cannot be used to retrieve a single observation. See also Sections 2.2.17 and 2.2.18

2.2.10 delta_redshift_lim

For a particular cluster maximum delta_redshift (see Sec. 2.2.11) allowed for members. These limits are calculated as $3 \cdot \sigma_v(1+z)$, where $sigma_v$ is the velocity dispersion of the cluster. For low ($z = 0.2$) and intermediate ($z = 0.75$) redshift clusters, the velocity dispersion of a simulated cluster is estimated form its halo mass using the relation of Munari et al. (2013). For high redshift simulated clusters ($z = 1.25$) the velocity dispersion is fixed to 2 000 km/s The delta_redshift_lim parameter is used to determine cluster membership as described in the paper.

2.2.11 delta_redshift

Difference between the redshift of the object (final_redshift, see Sec.2.2.5) and the systemic redshift of the cluster (fixed to be $z_{\rm cluster} = 0.2, 0.75$ or 1.25 depending of the redshift of the box), i.e. final_redshift$-z_{\rm cluster}$. Used to estimate cluster membership as described in Muñoz Rodriguez et al. 2022.

2.2.12 lgssfr

$\log_{10}$ of the specific star formation rate of the object, estimated as $\log_{10}$(obs_sfr/obs_sm), where obs_sfr and obs_sm are listed above (see Sec.2.1.7 and Sec. 2.1.11). This is used to determine magnitudes of **star-forming** galaxies

2.2.13 lgssfr_q_remap

$\log_{10}$ of the specific star formation rate of the object estimated using Schreiber et al. (2015) main sequence. For star-forming galaxies, values are drawn from the main sequence plus a random scatter of 0.2. For passive galaxies the specific star-formation rate is fixed to be 1-2 dex lower than the main sequence (depending on redshift). The shift is empirically determined to match observational results (see Georgakakis et al., 2020, for details). This is used to determine magnitudes for **passive** galaxies

2.2.14 SF_Schreiber

Boolean that indicates if a galaxy is consider star-forming (True) or quenched (False) relative to the main sequence of Schreiber et al. (2015).

2.2.15 [band]_qUM

Apparent magnitude assigned to galaxies and AGN using the lgssfr_q_remap from UniverseMachine. [band] corresponds to IRAC1 at redshifts of 1.25 and R_PRIME for redshift 0.2 and 0.75

2.2.16 [band]_SFRq_remap

Apparent magnitude assigned to galaxies and AGN using the lgssfr from UniverseMachine. [band] corresponds to IRAC1 at redshift of 1.25 and R_PRIME for redshifts 0.2 and 0.75 Magnitude associated to the band, using SFR re-mapped both SF and quench calculated as described in Georgakakis et al. (2020) (see also Sec. 2.2.13). [band] corresponds to IRAC1 at redshift of 1.25 and R_PRIME for redshift 0.2 and 0.75.

2.2.17 reseed

Number of the re-seeding, used for internal calculation. This indicates the different AGN seeding realisations of the same cluster.

2.2.18 id_clust_reseed

Unique identifier of the parent cluster and reseeding (see descriptions above). Flag for internal calculation

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