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

Iván Muñoz Rodríguez

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Contents

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
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1 Overview

In Muñoz Rodriguez et al. 2022 we explore the role of the environment on AGN activation. We constructed 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 were populated after with AGN using specific accretion rate distributions derived from observations (Georgakakis et al., 2017; Aird et al., 2018). The explicit assumption of this latter step is the independence of the environment on AGN triggering. This is because observations used to construct the specific accretion rate distributions are based of deep-beam observations that cover mainly low-dense (field) halo populations. Therefore, predictions of the model will represent field population. To study the role of the environment we compared the fraction of AGN model predictions with real observations of cluster from Martini et al. (2013).

To make this comparison we implemented the selection effects of observations into the simulations. This requires to imitate observations of clusters in the mock catalogues. This is done using light-cones. The basic idea is to simulate the field-of-view (FOV, e.g. 20 arcmin) with the line-of-sight center into the center of the massive cluster. The objects that lie within the FOV are projected into the sky-plane. The objects that lie outside are discarded. For more details we refer to the Section 3.3 of the paper. The light-cone are composed by different structures, since they enclose all the object in a FOV for different redshifts. In practise this means that the observation contains the massive cluster, but also some background. Therefore, it is necessary to identify those members that actually belong to the observed cluster. This is done following observational selection as described in Section 3.4 of the paper.

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 conforms the necessary data to reproduce the results 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 next features in the catalogue come from the model of UniverseMachine (Behroozi et al., 2019). Publicly available catalogues can be found in https://www.peterbehroozi.com/data.html. In next subsections we provide a sum up of the features that we use from this model and a brief description

2.1.1 id

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

2.1.2 upid

-1 for central halos, otherwise, ID of largest parent halo. This has to main uses: first isolate central (parents) from satellites and construct the parent sample filtering by halo masses; second allows to study the "true" members of the clusters since satellites haloes have upid equal to the unique identification number of the parent.

[1] https://zenodo.org/record/7193557

2.1.3 vmp

Maximum halo velocity at the time when peak mass was reached (physical km/s). **This is not used**

2.1.4 v

Maximum halo velocity (physical km/s). **This is not used.**

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

True star formation rate ($M_\odot$/yr). This value does not account for systematic of the observations (see Behroozi et al., 2019). **This is not used**.

2.1.7 obs_sfr

Observed star formation rate, including random and systematic errors ($M_\odot$/yr). We used this value to calculate magnitudes associated to the galaxies following Georgakakis et al. (2020). These magnitudes are relevant to mimic selection effect of observations. See Section 2.2.16 and Section 3.4.3 of the paper for further details.

2.1.8 lgmp

$\log_{10}$ halo peak historical virial mass ($M_\odot/h$). Virial as defined in Bryan & Norman (1998). **Not used**

2.1.9 lgm

$\log_{10}$ halo virial mass ($M_\odot/h$). Virial as defined in Bryan & Norman (1998). This value describe 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

$\log_{10}$ true stellar mass ($M_\odot$). **Not used**

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 2.2.16 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. These are ultimately related to the AGN seeding processes where X-ray luminosities due to an AGN are associated to galaxies. And also the projection of these catalogues into the sky-plane.

2.2.1 lgLxGMedian, lgLxAMedian

X-ray luminosity (erg/s) using 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. **Not used**

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 of the object, peculiar velocities are accounted. Used select galaxy 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. In combination with FOV (see Sec. 2.2.7) used to estimate cluster membership as described in Muñoz Rodriguez et al. 2022.

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) used to estimate cluster membership as described in Muñoz Rodriguez et al. 2022.

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. r_parent is used to calculate 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 into the sky-plane. This number is the same for all the objects iwthin the same light-cone.

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 times the velocity dispersion of the parent halo times 1+redshift . For low and intermediate redshifts velocity dispersion for the mass of the cluster is calculated using Munari et al. (2013), for the highest redshift this velocity dispersion is fixed to 2 000 km/s. Used to estimate cluster membership as described in Muñoz Rodriguez et al. 2022.

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

re-mapped values for the specific star formation rate using Schreiber et al. (2015) main sequence. This is used to determine magnitudes of **passive** galaxies

2.2.14 Schreiber

Specific star formation rate from the main sequence described in Schreiber et al. (2015). For star-forming galaxies, values are drawn from the main sequence plus a random scatter of 0.2. For quiescent galaxies this value is shifted a quantity that has been fixed empiricaly to reproduce observations. See more details in Georgakakis et al. (2020).

2.2.15 SF_Schreiber

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

2.2.16 [band]_qUM

Magnitude associated to the band, using lgssfr values from UM for both star-forming and quench (see Sec. 2.2.12). [band] corresponds to IRAC1 at redshift of 1.25 and R_PRIME for redshift 0.2 and 0.75

2.2.17 [band]_SFRq_remap

Magnitude associated to the band, using SFR re-mapped both SF and quench calculated as described in Georgakakis et al. (2020) (see also Sec. 2.2.14). [band] corresponds to IRAC1 at redshift of 1.25 and R_PRIME for redshift 0.2 and 0.75.

2.2.18 reseed

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

2.2.19 id_clust_reseed

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

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