Data release
Scrutinising evidence for the triggering of Active Galactic Nuclei in the outskirts of massive galaxy clusters at $z \approx 1$

Iván Muñoz Rodríguez

June 10, 2024

Contents

1 Overview

In Muñoz Rodríguez et al. 2024 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.

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. We use the

Table 1: Overview of the mock catalogue content.

	Name	Units	Description
UniverseMachine	id	-	2.1.1
	upid	-	2.1.2
	r	kpc/h (comoving)	2.1.3
	lgmp	$\log_{10}(\mathrm{M}[\mathrm{M}_\odot/h])$	2.1.4
	lgm	$\log_{10}(\mathrm{M}[\mathrm{M}_\odot/h])$	2.1.5
	lgsm	$\log_{10}(\mathrm{M}[\mathrm{M}_\odot])$	2.1.6
	lgob_sm	$\log_{10}(\mathrm{M}[\mathrm{M}_\odot])$	2.1.7
This paper	x, y, $\mathrm{z_{obs}}$	Mpc/h (comoving)	2.2.1
	vx, vy, vz	km/s (physical peculiar)	2.2.2
	dist_obs	Mpc/h (comoving)	2.2.3
	dRA, ddec	-	2.2.4
	redshift	-	2.2.5
	peculiar_redshift	-	2.2.6
	final_redshift	-	2.2.7
	angle_los	rad	2.2.8
	z_box	-	2.2.9
	ring	-	2.2.10
	lgLx[model]	erg/s	2.2.11
	flux_pl[model]_[band]	erg/s/cm^2	2.2.12
	area_[model]_[band]_[observation]	-	2.2.13

mock catalogues to characterise the impact of cosmic variance on the observed overdensities on the AGN radial distributions of Koulouridis & Bartalucci (2019).

The simulations are compared with observations following a forward modelling approach. This requires to apply the selection effects of particular observations in the mock catalogues. The N-body simulation boxes are projected onto the sky to generate light cones centered on halos with similar properties to the observations.

In what follows we detail the content of the dataset of the paper, necessary data to reproduce the results, in concrete Figures 7, 8, 9, 10 and 12. We provide the code to reproduce these figures via Github repository [1].

2 Dataset

The dataset consist in a collection of 400 light-cones generated which cover a redshift range $z = 0 - 3$. There are two sets of 100 light cones which point to the clusters with UniverseMachine id = 830644447 and 7793510527 in the box at a redshift $z = 0.94$. These two clusters are selected to have similar properties as the observed by Koulouridis & Bartalucci (2019). The other 200 light cones point to random locations in the same box and they are used to subtract the background expectation. The latter are organised as two sets of 100 light cones which each of them has the same redshift structure as each of the cluster light cones. See details on the light cone construction on Section 3 of the paper.

The catalogues can be accessed through Zenodo[2].

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.

[1] `https://github.com/IvanMuro/rad_dist_data_release`
[2] `https://zenodo.org/uploads/11446317`

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.

2.1.3 r

Halo virial radius as defined in Bryan & Norman (1998) (comoving kpc/h). This value is used to select cluster members.

2.1.4 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.

2.1.5 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 **??** and Section 3.4.3 of the paper for further details.

2.1.6 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.

2.1.7 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 **??** and **??**, 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 x, y, z_{obs}

Coordinates of the haloes after projecting into the sky-plane with respect to the observer at $z = 0$. Note that these x, y, z do not correspond to the ones quoted in UniverseMachine, and for the same objects they are in different light cones. These parameters are used to construct the light cones.

2.2.2 vx, vy, vz

Velocities of the haloes after projecting into the sky-plane. Note that these x, y, z do not correspond to the ones quoted in UniverseMachine, and for the same objects they are different in different light cones. Used to calculate peculiar and redshifts, see Sec. 2.2.6 and Sec. 2.2.7.

2.2.3 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. 2.2.7 and Section 3.4.3 of the paper.

2.2.4 dRA and ddec

Offset in right ascension (dRA) and declination (ddec) of the haloes with respect to the centre of the light cone. These are used to calculate the distance of the haloes to the cluster centres (see also angle_los in Sec. 2.2.8) and associate them to the different radial distance rings (see Sec 2.2.10).

2.2.5 redshift

Redshift associated to the comoving distance of the haloes with respect to the observer.

2.2.6 peculiar_redshift

Peculiar redshift of a given halo calculated using the particular velocities of the haloes

2.2.7 final_redshift

Redshift assigned to the object including the effect of peculiar velocities.

2.2.8 angle_los

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

2.2.9 z_box

Redshift of the box of the corresponding halo. Since light cones are constructed by stacking boxes at different redshifts to capture the evolution of the Universe, this column can be used to identify which is the UniverseMachine box where this halo is from.

2.2.10 ring

Number of the anulii corresponding to the projected R_{500} radial bin, i, with inner and outer radius of $i/2 \cdot R_{500}$ and $(i+1)/2 \cdot R_{500}$.

2.2.11 lgLx_[model]

X-ray luminosity (erg/s) using different the models: `AMedian`, `GMedian`, `Gauss_mu-2.00_sigma0.50`, `Gauss_mu-1.50_sigma0.25`, `Gauss_mu-1.25_sigma0.10`. `AMedian`, `GMedian` correspond to Aird et al. (2018) and Georgakakis et al. (2017) 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. 2.1.7). The other three models correspond to a specific accretion rate distribution with the shape of a Gaussian with mean and scatter as indicated in their names (see details in Muñoz Rodríguez et al., 2023).

2.2.12 flux_pl[model]_[band]

X-ray flux (erg/s/cm^2) associated to the correspondent X-ray luminosity (lgLx_[model], see Section 2.2.11) by assuming a spectral shape of a power-law with index $\Gamma = 1.4$ (similar to the diffuse X-ray background; Akylas et al., 2012). Band can take values: `soft` (0.5-2 keV), `hard` (2-10 keV) or `full` (0.5-10 keV)

2.2.13 area_[model]_[band]_[observation]

Probability of detecting an AGN according to its flux and ring i.e., it is the value of the area curve at the corresponding ring and flux (see Section 2 and 3 of the paper for further details). Observation can take values `pl26` (corresponding to the cluster PLCKG266.6-27.3) or `13469` (corresponding to the cluster SPT-CLJ2146-4633).

References

Aird J., Coil A. L., Georgakakis A., 2018, , 474, 1225

Akylas A., Georgakakis A., Georgantopoulos I., Brightman M., Nandra K., 2012, , 546, A98

Behroozi P., Wechsler R. H., Hearin A. P., Conroy C., 2019, , 488, 3143

Bryan G. L., Norman M. L., 1998, , 495, 80

Georgakakis A., Aird J., Schulze A., Dwelly T., Salvato M., Nandra K., Merloni A., Schneider D. P., 2017, , 471, 1976

Klypin A., Yepes G., Gottlöber S., Prada F., Heß S., 2016, , 457, 4340

Koulouridis E., Bartalucci I., 2019, , 623, L10

Muñoz Rodríguez I., Georgakakis A., Shankar F., Allevato V., Bonoli S., Brusa M., Lapi A., Viitanen A., 2023, , 518, 1041