possChallenge #3: Do observers and simulators measure the same quantity of ICL?

Slack channel on LSSTC: # lsb-challenge3

Key products: Mock images and predictions of ICL quantity from simulations compared to quantity measured using observational techniques.

People: (41)
Aaron Watkins
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+Amaël Ellien
Amir Ebadati Bazkiaei
+Annalisa Pillepich
+Anthony Gonzalez
Brandon Kelly
*Chris Collins
*Chris Mihos
+Cristina Martinez-Lombilla
Dara Norman
Dino Bektesevic
*Enrica Iodice
Facundo Gómez
Fergus Longbottom
+Garreth Martin
Gaspar Galaz
Hector Hernandez toledo
Javier Roman
Jeff Carlin
*Johan Knapen
Jose Antonio Vazquez Mata
Lee Kelvin
Lee Spitler
*Louise Edwards
Mariano Dominguez (email?)
Markus Dirnberger
Michael Rich
+Mireia Montes
+Nina Hatch

Peregrine McGehee
+Rhea-Silvia Remus (+student?)
-Rodrigo Cañas
+Rossella Ragusa
+Sarah Brough
Sean McGee
*Sugata Kaviraj
Tjitske Starkenburg
Yannick Bahé
+Yolanda Jiménez-Teja
*Yuanyuan Zhang

Leader: Sarah Brough (s.brough@unsw.edu.au)
Former Leader: Mireia Montes (Contact: mireia.montes.quiles@gmail.com)

Ideas:

- Need to make a list of observers and simulators/simulations. Simulations must span a wide range of cluster masses.
- We should agree on a definition for ICL. Once we all agree on that, simulators can measure the "real" ICL in simulations. For me, the best one is the stars that are not bound to any galaxy but follow the cluster potential. I am strongly against the in-situ/ex-situ separation (MM).
- From those simulations, produce mock images that replicate realistic observations (noise/psf) of the Rubin Obs/LSST (the survey). (!! The data processing is going to eliminate some diffuse light already !!---> Challenge #1)
- The observers will do their magic to measure the ICL in different ways.
- Compare!

2020/4/22 First Meeting:

Attendees: Mireia Montes (MM), Sarah Brough, Chris Collins, Sean McGee, Brandon Kelly, Chris Mihos, Sugata Kaviraj, Anthony Gonzalez, Rodrigo Canas, Cristina Martinez-Lombilla, Garreth Martin, Aaron Watkins. (12 people)

Organise vote for leader - Voted for Mireia Montes to lead the challenge.

Discussion:
- How to define ICL in simulations. Not easy, every group has its own definition. Ideal definition: "stars that are not bound to any galaxy but follow the cluster potential" . Hard to say where 1 galaxy ends and the other starts even in simulations. Also different simulations, different properties: different sizes, different stellar mass functions (important in the faint end as it will change the fraction of intrahalo light that we get).

Rodrigo's approach: Particle to be ICL has to be far away physically/kinematically from other particles. Will need to invite other simulators. What are likely differences between different simulations?

We can try a non-parametric approach: Could examine surface brightness profiles from different simulations - if similar then easier for observers to analyse.

We can run Rodrigo's pipeline in other simulations (adapted to the particulars of each simulation) and get our ICL.

Link to Rodrigo's paper: https://arxiv.org/pdf/1908.02945.pdf

Action Item: List of simulators to contact:

- Rodrigo Cañas
- Isaac Alonso-Asensio isaacaa@iac.es (Claudio Dalla Vecchia, caius@iac.es, PhD Student) / Yannick Bahé (C-EAGLE) bahe@strw.leidenuniv.nl
- Annalisa Pillepich (Illustris) pillepich@mpia-hd.mpg.de
- Sukyoung Yi (Horizon-AGN) YI@YONSEI.AC.KR (are these simulations big enough to have big clusters?)
- Rhea-Silvia Remus / K. Dolag (Magneticum) rhea@usm.lmu.de

##

Hi, Chris Mihos here, adding one thought: we talked about ways to "translate" simulation results to observational space. Here's an early example of trying that, from Rudick+11 (a decade+ old set of simulations -- how many years is that in dog years?). We measured ICL in simulations as particles unbound from any individual galaxy, and then also made projected surface brightness maps. We then asked: for the particles that contribute to the surface brightness below some level, what fraction of them are unbound ICL? We got a result that looked like this (different lines

are different simulated clusters):

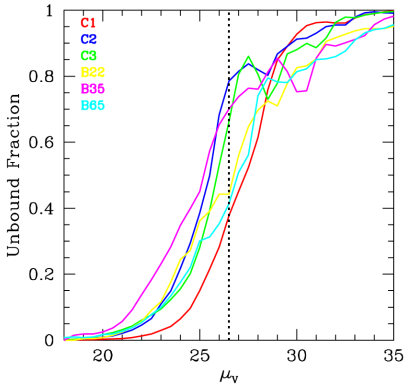


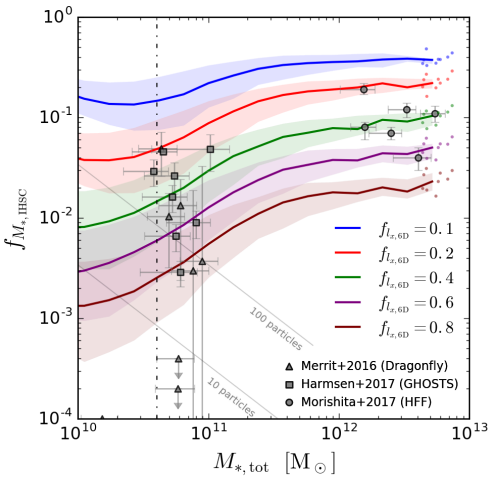
Figure 6. Fraction of luminosity at a given surface brightness which is contributed by unbound stars for each of our clusters.

The idea being that if you measure down to a surface brightness of X, you are seeing material that has an unbound likelihood of Y (roughly speaking). Maybe doing an updated version -- or variant -- of something like this would be constructive? Clearly newer simulations and tools like Rodrigo's VELOCIRAPTOR work would produce much better "next generation" results compared to our earlier work…. Thanks Chris!

Hi everyone, it's Rodrigo again. Here are some of the plots I mentioned during the zoom meeting so you have a better idea of what I was talking about.

The method that we introduced to identify galaxies and at the same time separate the diffuse component (Stellar halo, IGL, ICL; https://arxiv.org/abs/1806.11417), is adaptive and requires as input parameters the mean interparticle spacing of the simulation and a linking length factor, which is the one that changes how much mass is kept in the galaxies or is assigned to the ICL.

This first plot shows the mass fraction that we estimate is in the ICL at different masses for different parameter values, which ultimately define a phase-space density cut (https://arxiv.org/abs/1908.02945). In the paper we argued that parameters can be chosen to reproduce a set of observational estimates given the characteristics of the observation/survey.



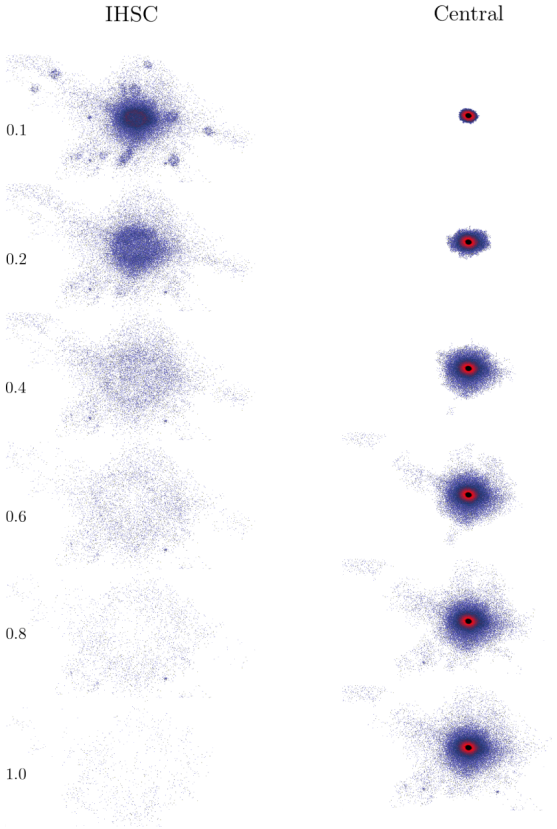
However, this does not mean that we don't have any idea of what parameter we should choose, because we know that the properties of galaxies (satellites and BCGs) do not have to be affected by this separation of galaxies and ICL.

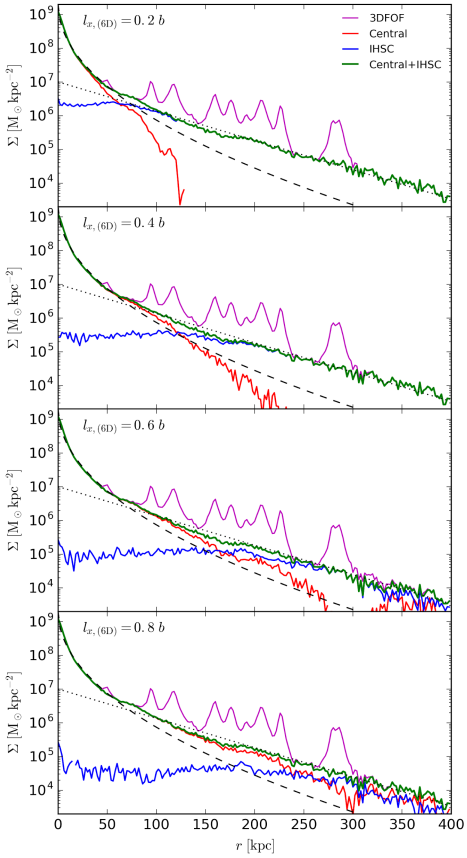
Below I am showing a surface density visualization (left) of how this parameter changes the mass and size of the

central galaxy of a group and how the ICL changes as well (further explained in the paper).

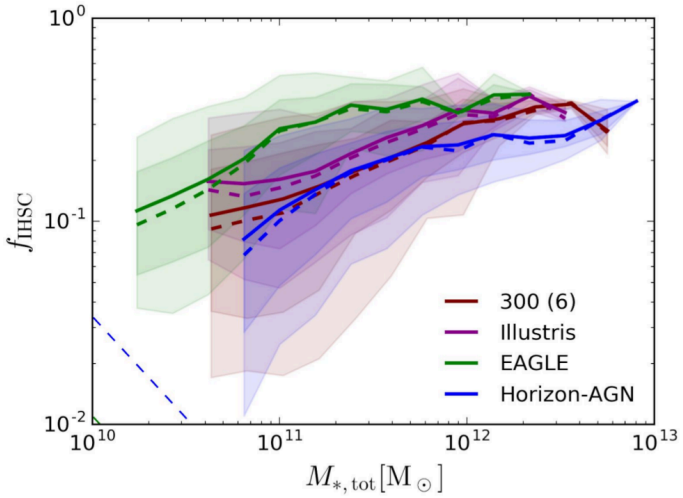
The plot on the right shows the surface density of all the stellar material in the group, the central and the ICL, for some values of such parameter, *l_x6d.* The dotted and dashed lines are just used to guide the eye (not proper fits). The point of these plots is to show that although we could arbitrarily choose a *l_x6d* value to shift the stellar mass - ICL fraction relation (above plot), there are clearly very small values cut off the outskirts of the galaxies (both central and satellites), and very large ones basically assign all particles to the central galaxy.

For our https://arxiv.org/abs/1908.02945 paper we sticked with 0.4 one, as the cut off is not that sharp, and it matches at both MW and galaxy cluster masses the estimated stellar halo/ICL fraction from observations.

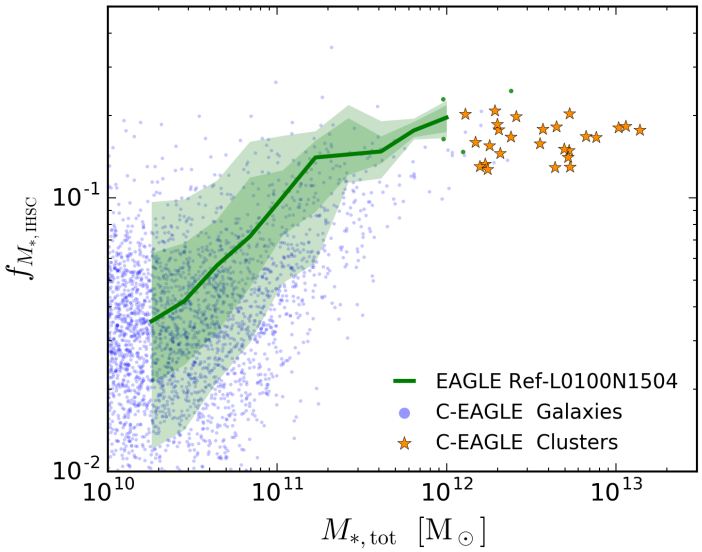




Finally, the expected fraction on the ICL will depend on the subgrid physics implementations of each simulation as they predict different sizes and stellar mass content. Below I have an oldish plot where I started to explore this for Eagle, Horizon-AGN and Illustirs. I have already talked with Romeel Dave to use SIMBA and MUFASA data, as well as with Rhea-Silvia to add the Magneticum simulations to this plot.



And just in case you were wondering what happens for massive clusters, here are some measurements for the Hydrangea/C-EAGLE clusters (most massive ones are ~2-3 10^15 M_sun).



Please feel free to contact me if you have any comments or questions =).

##

2020/7/15 Meeting:

Attendees: Mireia Montes (MM), Brandon Kelly, Anthony Gonzalez, Sarah Brough, Chris Collins, Sugata Kaviraj, Chris Mihos, Garreth Martin

Agenda:

- Summary of simulations. At the end of the document.
- Define the things we want from simulators:
    - Halo mass range of groups/clusters? (Assess things like: is one definition good for all?)
    - Redshift? Evolution ICL / BCG + ICL / BCG
    - Random orientations of the clusters
    -

- Mock observations:
    - We should provide:
        - Filters
        - PSFs
        - Depths
        - Other characteristics: Noise, ...?

...And if we have time we can discuss measurements. ;-)

Create mock images:

From Allison Merritt (https://arxiv.org/abs/2004.11402)

I made the mock images in 2 steps:

1. adaptively smoothed the particles in 3D, and then collapse to a 2D image along one of the axes to produce “idealized” images in light or mass. For this smoothing, I used a Gaussian kernel where the width was the distance to the 3rd nearest particle (but this was just a choice .. you can use the distance to the nth particle in general where n does not have to be 3).

2. for the light images (now in 2D), I convolved them with the Dragonfly PSF, scaled them to ADU using our ZP, and then actually stuck them in a real section of one of our reduced fields. In principle you could estimate the noise and surface brightness limits, but I wasn’t confident that I could simulate realistic surface brightness limits so I just used the real data.

- Should we do the same in HSC data? DESC? Idealized version?

List of actions to do:

- Contact simulators (MM)
- Contact Claudia and Rodrigo to see in what stage they are in the image making (MM)
- Provide code for simulators to separate between ICL and galaxies. (Rodrigo)
- Make mock observations of groups/clusters. (See above)

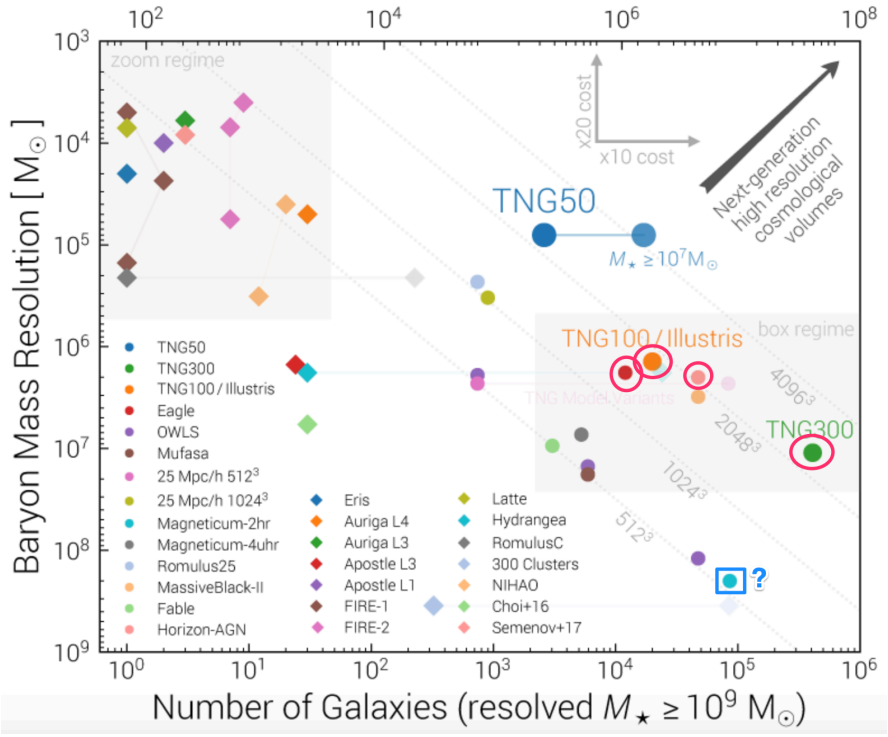
Codes from Allison: https://github.com/atmerritt/observingtng

##

Key Milestones with person/s responsible with Deadlines:

- Mireia to contact simulators by the end of ???
- (Here some steps that depend on the simulators)
- What ranges of masses/redshift we want to explore? That will determine what simulations we use.
- Creation of images:
    - Where do we obtain mock images to insert the clusters/properties for LSST?
    - Is there a model PSF? Should we use instead an HSC PSF for the moment? I know Roberto Baena is working on deriving large-scale PSFs for HSC.
    - Set a Github folder for the challenge so everybody can contribute to the coding? (and track changes)
    - Simulation -> convolve with a kernel to smooth it (making it more realistic) -> Add to images/or add noise -> convolve with PSF (or the other way around? PSF first, add later?)
    - Random orientations of the clusters

2020/7/16 SUMMARY of SIMULATIONS:



Illustris TNG300/100:

(Pillepich2018b, Merritt2020)
Mesh-code: AREPO
Volume: 302.6^3 (Mpc^3)
Side = 205 Mpc/h = 302.5 Mpc
Particle resolution (baryonic) = 7.44 x 10^6 Msun/h
Particle number = 2 x (2500)^3
Resolution in mass (spatial) is 8 times (2) worse than TNG100.
Most massive object : 1.5x 10^15 Msun // TNG100: 3.8x10^14 Msun

- In particular, in our galaxy physics model, stellar masses and star formation rates typically increase with better resolution. This is particularly problematic for TNG300, because we would like to exploit the powerful statistics of the large volume, but with galaxy properties as would be obtained at TNG100 resolution.

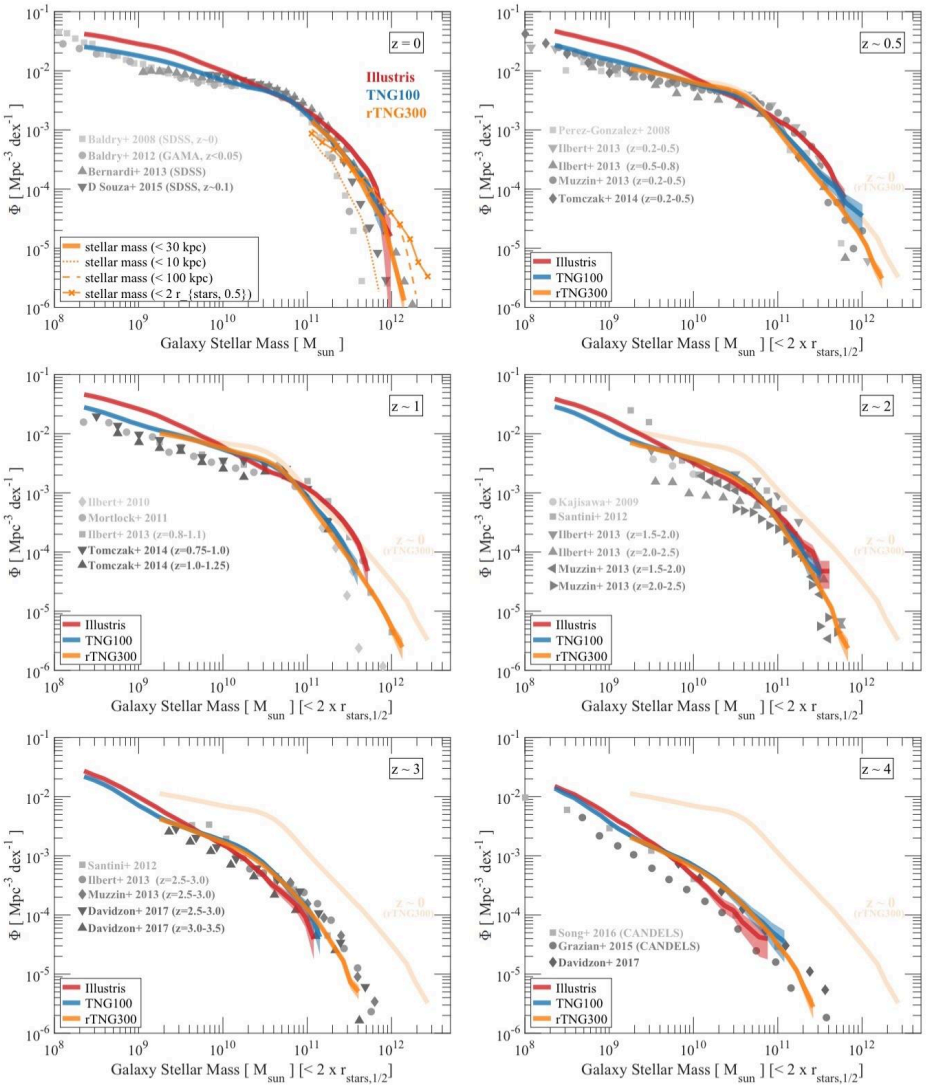


Figure 14. The TNG galaxy stellar mass functions after the Epoch of the Reionization, from $z \sim 4$ to today. Unless otherwise specified, we show results from the simulations by accounting for all the stellar mass within twice the stellar half mass radius (thick colored curves from $z = 0.5$ to 4). At $z = 0$, we emphasize the importance of the galaxy mass definition by providing the predictions from TNG300 for different aperture measurements: 30 kpc (for all runs, thick curves), 10kpc (orange dotted), 100 kpc (orange dashed) and twice the stellar half mass radius (orange crosses). At $z > 0$, we report in light orange the rTNG300 mass function (within twice the stellar half mass radius), for reference. A selection of observational data points is included for comparison in grey symbols, all converted to Chabrier IMF (Baldry et al. 2008, 2012; Bernardi et al. 2013; D'Souza et al. 2015; Pérez-González et al. 2008; Mortlock et al. 2011; Ilbert et al. 2013; Muzzin et al. 2013; Tomczak et al. 2014; Kajisawa et al. 2009; Santini et al. 2012; Davidzon et al. 2017; Grazian et al. 2015).

The situation in TNG100 is improved with respect to Illustris by a factor of a few, but simulated galaxies are still more abundant than observed for stellar masses of 10^9 at z ~ 1 by up to a factor of 2 (depending on the observational sample at hand; Pillepich et al. 2018b).

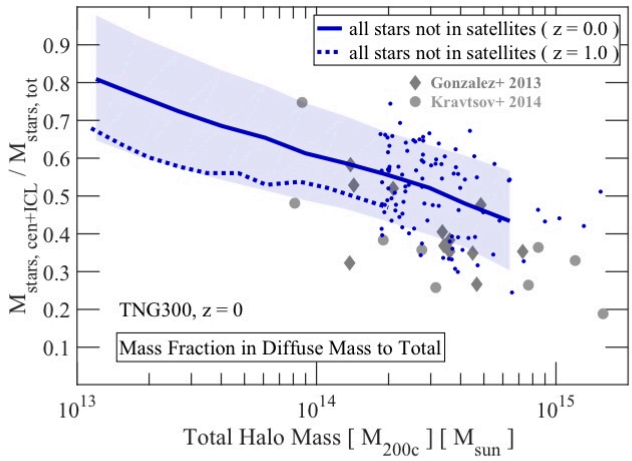


Figure 10. Stellar mass fractions in the various luminous components of groups and clusters, as a function of total halo mass. From top to bottom: stellar mass in the central galaxy to the total stellar mass out to the virial radius; stellar mass in the ICL or outskirts to the total stellar mass; mass in the ICL or outskirts to the stellar mass in the diffuse components (central + ICL); stellar mass in the diffuse component (central + ICL) to total stellar mass out to the virial radius. Annotations are as in Figure 9, with all solid curves, symbols and annotations referring to $z = 0$ relations, but for the dotted median curves, denoting $z = 1$ results.

Galaxy stellar masses in TNG100-2, for example, are approximately 40 percent lower than in the fiducial TNG100-1. On the other hand, galaxy stellar sizes in TNG decrease towards higher resolution, and this holds true for both the in-situ and ex-situ stellar components. Later, Pillepich et al. (2019) extended these convergence checks to TNG50 and showed that resolution affects the sizes of low mass galaxies (Mstell,true ≤ 109 −1010M) more strongly than those of high mass galaxies, and particularly at lower redshifts. They showed that galaxy sizes in TNG100 are converged to better than 20 − 40 percent after z = 2, but that the fraction of disk galaxies increases with resolution.

EAGLE :

Code: GADGET-3 modified (Anarchy)
(Bahé2017)

Hydrangea:

24 zoom-in galaxy clusters. 10-25 comoving Mpc (out to 10 virial radius, 24 of the 30 C-EAGLE clusters).
Parent simulation: 3200^3 cMpc^3 only DM
M200c = 10^14–10^(15.4) M
Particle resolution (baryonic) = 1.81x10^6 Msun

Particle resolution (DM) = 8.01x10^10 Msun
physical softening length of 0.7 kpc

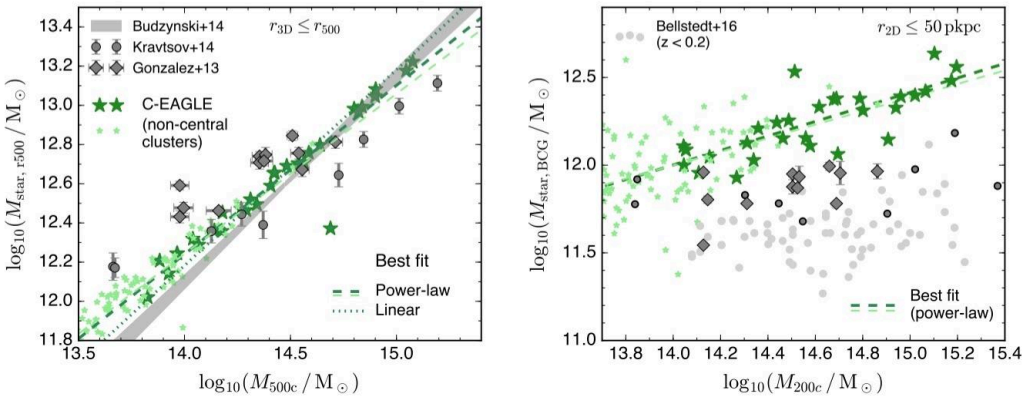


Figure 4. Left: stellar mass of C-EAGLE clusters within r_{500c} (green stars) as a function of true halo mass, compared to several observational data sets (grey points and band). Large dark green symbols represent the 30 central clusters within each simulation, other clusters within the simulation volume (with $M_{200c} \geqslant 5 \times 10^{13}{\rm M}_\odot$) are shown as small light green stars. **Right:** stellar mass of the simulated BCGs as a function of halo mass, measured within a circular aperture of $R_{2D} < 50$ pkpc, compared to observations. In both panels, dashed dark green lines show the best power-law fit to the simulated relation for central clusters with slopes of $\alpha = 0.86 \pm 0.05$ (within r_{500c}) and $\alpha = 0.41 \pm 0.06$ (for the BCGs); thin light green lines show the analogous fits for non-central clusters. In the left-hand panel, the dotted dark green line additionally shows the best linear fit, corresponding to a stellar fraction of 1.51 per cent. Although the total mass of stars in the halo (within r_{500c}) is reproduced well by the simulations, BCGs are too massive by a factor of ∼3. Non-central ('secondary') clusters follow the same relation as their central counterparts.

BCG masses 0.3 dex higher than z =0 observations (R_2D< 50 kpc) (0.6 dex compared with z<0.2). Also, the star formation rates of the central cluster galaxies within the central 15 pkpc (not shown) are all in the range from 1 to 10 M yr−1 , whereas only <50 per cent of observed central cluster galaxies show evidence for star formation at this level

Need to make a list of observers and simulators/simulations. Need to make a list of observers and simulators/simulations.

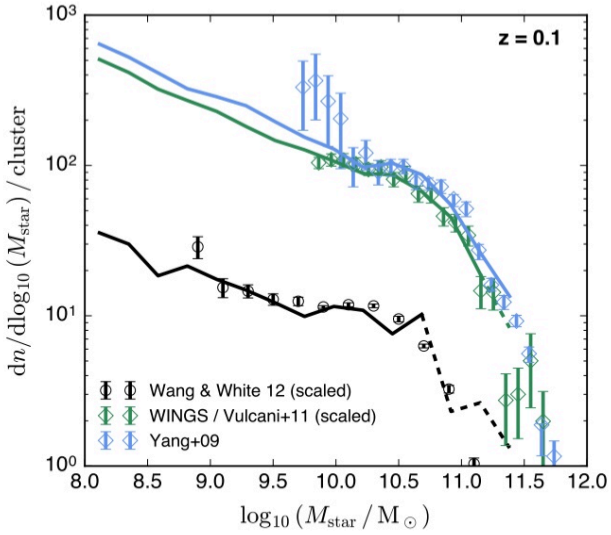


Figure 5. Galaxy stellar mass function (GSMF) at $z = 0.101$ for satellites in the C-EAGLE simulations (solid lines, dashed where there are < 10 galaxies per 0.25 dex bin) compared to observations (open diamonds). The three different lines represent galaxy selections approximately matched to the respectively-coloured observational survey: $14.0 \leqslant \log_{10}(M_{200c}/\mathrm{M}_\odot) < 14.5$, $R_{2D} < 300$ pkpc (black); $14.5 \leqslant \log_{10}(M_{200c}/\mathrm{M}_\odot)$, $R_{2D} < 0.6r_{200c}$ (green); $14.4 \leqslant \log_{10} M_{200c}/(\mathrm{M}_\odot h^{-1}) < 14.7$, all halo members (blue). Overall, the simulations achieve an excellent match to the observations.

GSMF at lower masses discrepancy with observation maybe due to overly efficient quenching of low mass galaxies in the simulation?

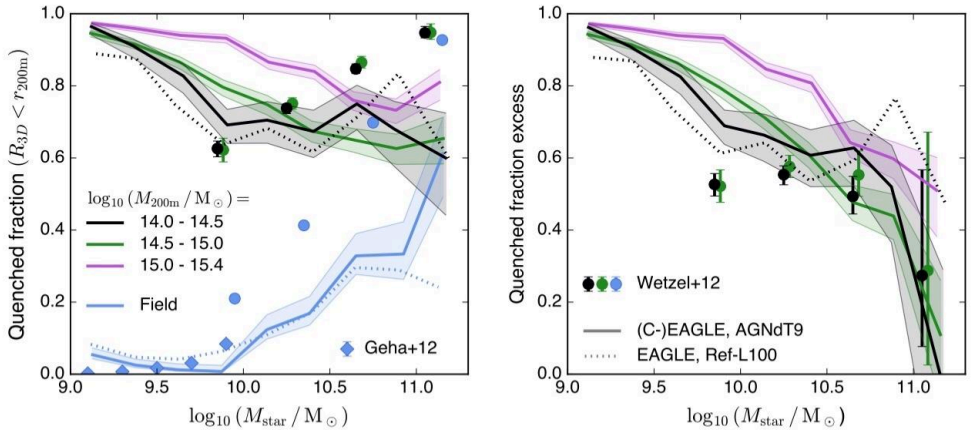


Figure 6. Left: Quenched satellite fraction within $r_{3D} \leqslant r_{200m}$, in bins of cluster mass (differently coloured solid lines) as a function of stellar mass. The blue solid line shows the corresponding trend in the field, i.e. centrals in the AGNdT9-L050 simulation from the EAGLE suite. Shaded bands indicate 1σ binomial uncertainties (Cameron 2011). The dotted blue and black lines are the corresponding trends from the EAGLE Ref-L100 simulation. Filled circles with error bars show the corresponding values from the SDSS DR7 analysis of Wetzel et al. (2012) and blue diamonds the observed quenched fractions of field dwarfs from Geha et al. (2012). In agreement with observations, simulated satellites show an enhanced quenched fraction compared to the field, albeit with discrepancies in the trends with $M_{\rm star}$ (see text for details). **Right:** The satellite quenched fraction excess, $(f_q^{\rm sat} - f_q^{\rm cen})/(1 - f_q^{\rm cen})$, which shows quantitative agreement between simulations and observations at $M_{\rm star} > 10^{10}\mathrm{M}_\odot$.

Left panel, observed fractions come from colours -> overestimation! That's why right panel. (M>10^10Msun)
For M~10^9Msun, the efficient quenching is produced by resolution effects.

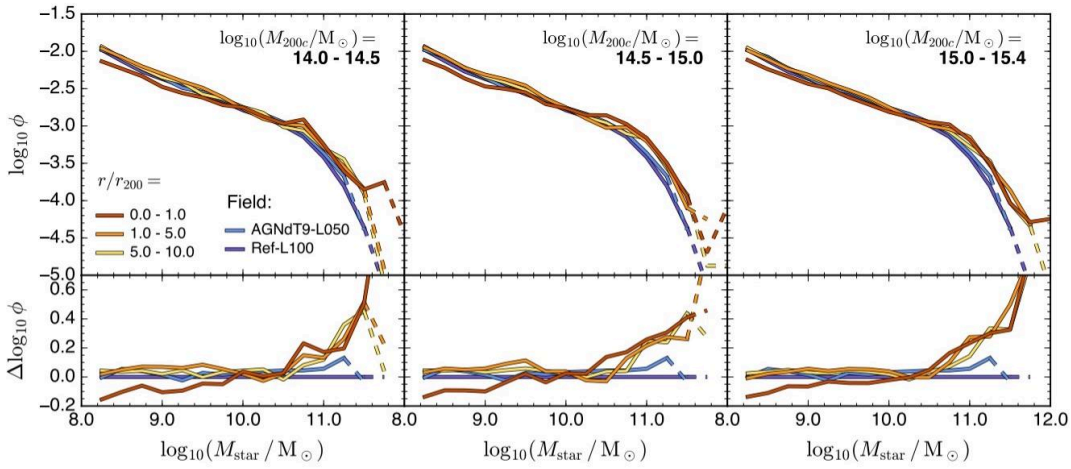
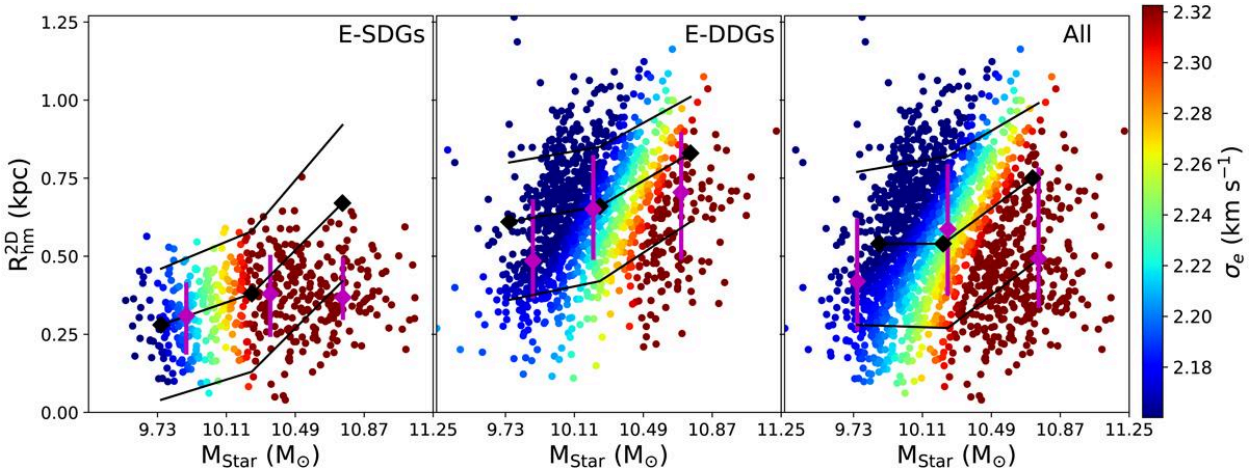


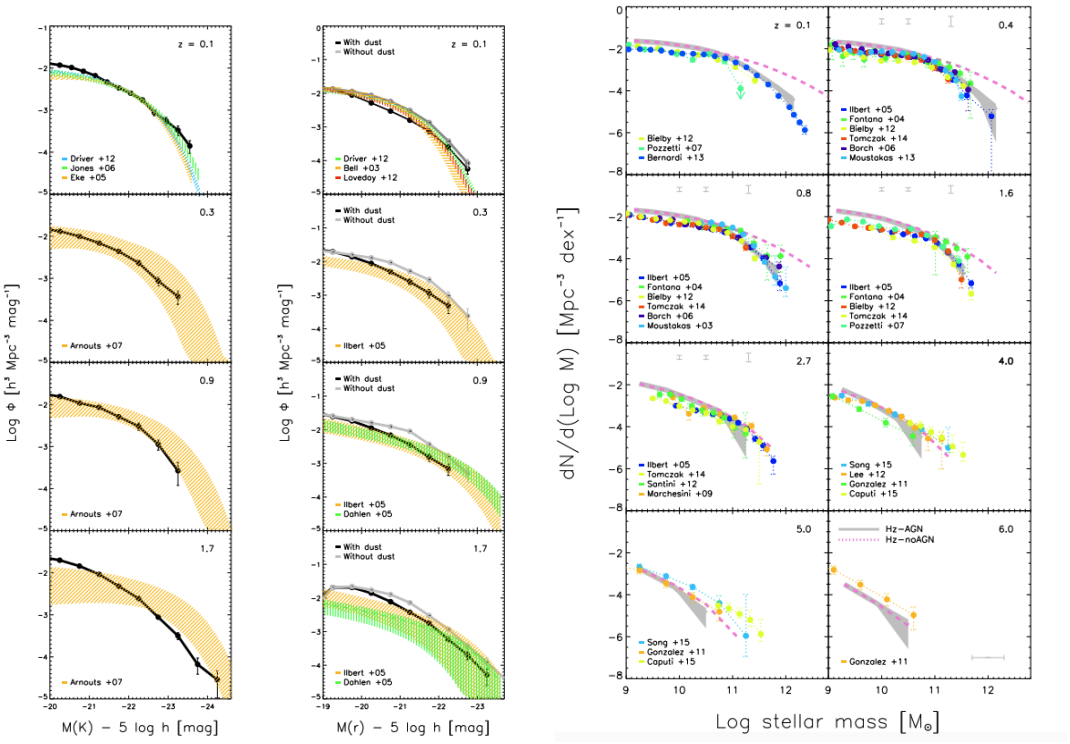
Figure 7. Top row: galaxy stellar mass function (GSMF) normalised to the total mass within the respective volume, $\phi \equiv \mathrm{d}n/\mathrm{d}\log_{10} M_{\mathrm{star}}/(M_{\mathrm{tot}}/10^{10}\mathrm{M}_\odot)$. Individual columns contain clusters of different M_{200c} (as indicated in the top-right corner). Differently coloured lines (dashed where there are less than ten galaxies per 0.25 dex bin) represent different radial zones in each cluster: inside r_{200c} (red); between 1 and 5 r_{200c} (i.e. the region containing a population of backsplash galaxies, orange); the far outskirts beyond 5 r_{200c} (yellow). For comparison, the mass functions from the AGNdT9-L050 (blue) and Ref-L100 (purple) EAGLE runs are also shown. **Bottom row:** logarithmic ratio between each GSMF and that from the Ref-L100 periodic box. All halo mass bins show an excess of massive galaxies in and around clusters, without a clear radial trend. Galaxies less massive than $\sim 10^{10}\,\mathrm{M}_\odot$, on the other hand, are deficient in the central cluster regions (red).

– Early- and late-type galaxies in the EAGLE simulations, called E-SDGs and E-DDGs, are found to follow stellar mass–size planes in global agreement with observations, principally for galaxies with stellar masses of ~10^10.3 M. Lower and higher mass galaxies show discrepancies, but are within the observed ranges reported by van der Wel et al. (2014). (Rosito2020) Black rombus van del Wel 2014



HORIZON-AGN:

Mesh-code: RAMSES
Physical resolution : 1 kpc
Stellar mass resolution: 2 × 10^6 Msun
DM mass resoluytion : 8 × 10^7 Msun
Size : (100/h Mpc)^3 -- equiv. at z=0 (142 Mpc)^3
Kaviraj et al. 2017



excess stellar mass to halo mass ratio for Horizon-AGN low mass haloes

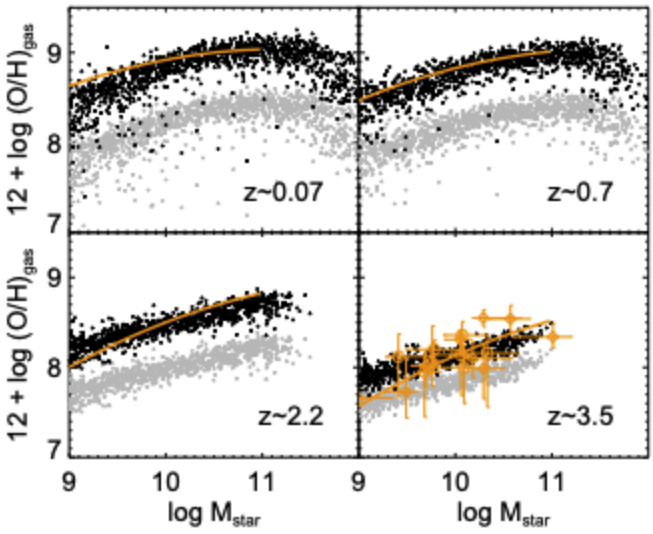
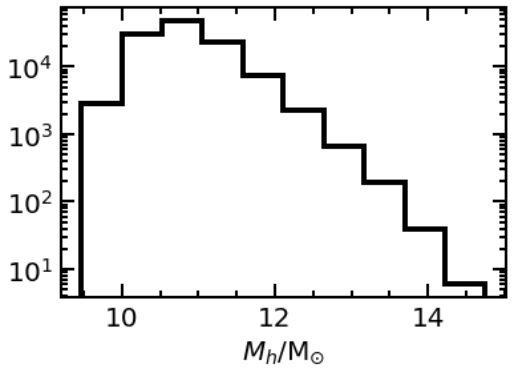


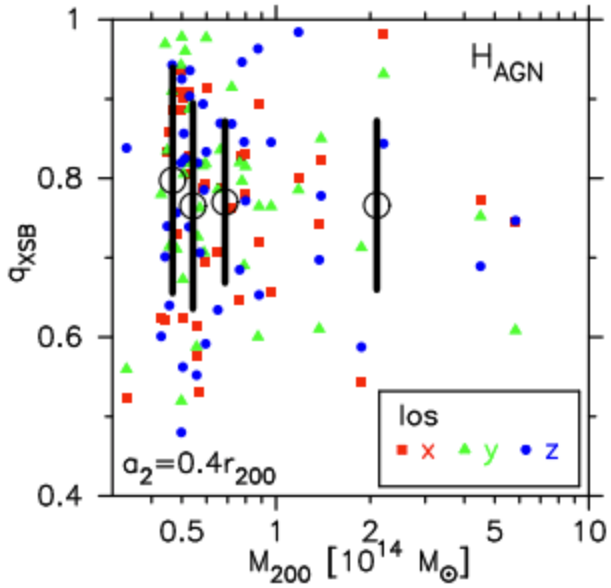
Figure 9. Calibration of the predicted mass-gas phase metallicity relations to osbervational data. The mass-gas phase metallicity relations predicted by Horizon-AGN are shown in grey. The observational data (Maiolino et al. 2008; Mannucci et al. 2009) to which we perform the calibrations to correct the simulated metallicities are shown in orange. Best fits to the observational datasets are shown using the orange lines. For the $z \sim 3.5$ dataset we also show the individual points to give an indication of the typical scatter around the best-fit lines (we only show one set of points for clarity and because the scatter is similar at all epochs). The corrected metallicities that are used for the analysis in this study are shown using the black points.

number of observed properties including the intrinsic alignment of galaxies (Chisari et al. 2015, 2016), density profile of massive galaxies (Peirani et al. 2017, 2019), cosmic star formation history over the redshift range 1 < z < 6 (Kaviraj et al. 2017), morphological diversity of galaxies (Dubois et al. 2016), alignments between galactic spin and the nearest filament Welker et al. (2019) and the ellipticity distribution of X-ray galaxy clusters (Paper I).

12 galaxy clusters (Dubois 2016) but 40 cluster-sized simulated DM haloes with MDM > 5 × 10^13Msun (Suto2017, Okabe2018, 2019) (< less than 10^15 Msun). Largest halo is $10^{14.75}$ Msun. (Thanks!)

Halo mass distribution:





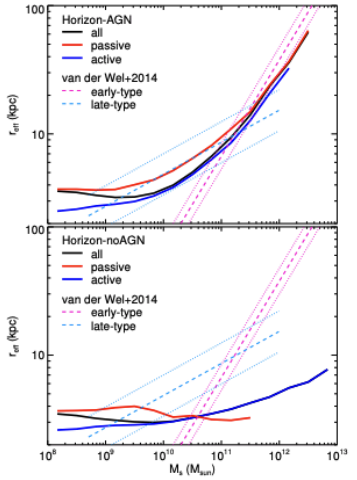


Figure 14. Size-mass relation for simulated galaxies in HORIZON-AGN (solid lines in top panel) and HORIZON-NOAGN (solid lines in bottom panel) at $z = 0.25$ compared to observations from van der Wel et al. (2014) for late-type galaxies (dashed cyan) and early-type galaxies (dashed magenta) and their corresponding scatter (in $\log r_{\rm eff}$) as dotted lines. We have plotted the result for our disc galaxies ($V/\sigma \geqslant 1$ in blue) and elliptical galaxies ($V/\sigma < 1$ in red). AGN feedback allows for more extended galaxies, while without AGN feedback, massive galaxies are too compact compared to observations. Discs and high-mass ellipticals in HORIZON-AGN closely follow the observational relation. However, low-mass ellipticals are not compact enough as their size approach the resolution limit (1 kpc).

This figure is to see the sample of clusters.
Dubois et al. 2016.

Cañas et al. 2020: https://arxiv.org/pdf/1908.02945.pdf

MAGNETICUM:

Table 1. Magneticum simulations used in this work.

	Box Size	$N_{\rm part}$	$m_{\rm Star}$	$\epsilon_{\rm Star}$
Box2b hr	910 Mpc	2×2880^3	$3.5 \times 10^7\ M_\odot/h$	$2\ \mathrm{kpc}/h$
Box4 uhr	68 Mpc	2×576^3	$1.9 \times 10^6\ M_\odot/h$	$0.7\ \mathrm{kpc}/h$

Remus et al. 2017
Box2b: we classify all structures with masses of Mtot > 2 × 1014 M as clusters, 890 objects. Box4:, there are no massive galaxy clusters, but resolution enables us to utilize halos with masses down to 1×1013 M < Mtot < 1×1014 M, Including the three clusters and 35 groups

Simulation[◇]	L [Mpc][⋆]	Ω_m	f_b	σ_8	$\epsilon_{DM}^{z=0}$ [kpc]	$m_\star$ [$M_\odot$][♠]	$\log_{10}(M_{20})$[▽]	$N_{\rm sam}$[†]	Calibration
BM	596	0.3175	0.154	0.834	5.96	1.2×10^9	15.6	9430	GSMF, CL $f_{\rm gas}$
B100	143	0.2793	0.166	0.821	2.86	1.4×10^8	14.1	96	GSMF, CL $f_{\rm gas}$
MGTM	500	0.2726	0.167	0.809	5.33	5.0×10^7	14.9	4207	SMBH, Metals, CL $f_{\rm gas}$
TNG300	303	0.3089	0.157	0.8159	1.48	1.1×10^7	14.6	1146	See Pillepich et al. (2018a)

◇ See text for description of acronyms.
⋆ Comoving simulation cube length except for MACSIS (subset of the BM data), which subsamples a 3.2 Gpc cubic volume.
♠ Initial stellar particle mass.
▽ Upper limit of LLR regression at $z = 0$, the 20th most massive halo mass, in $M_\odot$.
† Number of halos with total mass, $M_{200c} > 10^{13.5} M_\odot$. The number above $10^{13.8} M_\odot$ for BM is ≈ 4400.

(TNG300), and the 500 Mpc high-resolution box 2b from Magneticum Pathfinder (MGTM) — with characteristics mesh hydroydynamics solver, AREPO (Springel 2010). As detailed in Pillepich et al. (2018b), the stellar mass functions

Uhm??? https://arxiv.org/pdf/2001.02283.pdf

Simulation Name	Size $[Mpc/h]$	n. part	m_{dm} $[M_\odot/h]$	m_{gas} $[M_\odot/h]$	ϵ $[kpc/h]$	$\epsilon_\star$ $[kpc/h]$
Box4/uhr	48	$2 \cdot 576^3$	$3.6 \cdot 10^7$	$7.3 \cdot 10^6$	1.4	0.7
Box2b/hr	640	$2 \cdot 2880^3$	$6.9 \cdot 10^8$	$1.4 \cdot 10^8$	3.75	2
Box0/mr	2688	$2 \cdot 4536^3$	$1.3 \cdot 10^{10}$	$2.6 \cdot 10^9$	10	5

Ragnanin et al. 2018 (In the first plot with all the simulations I think that they're taking the DM mass instead of the stellar mass resolution)

Remus et al. 2015 :

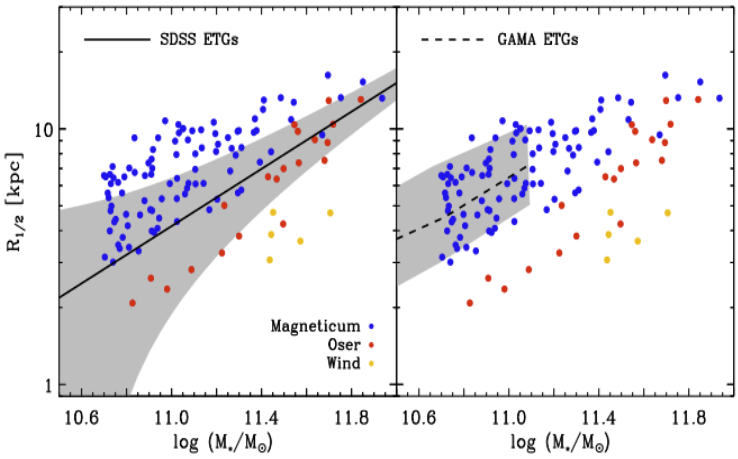
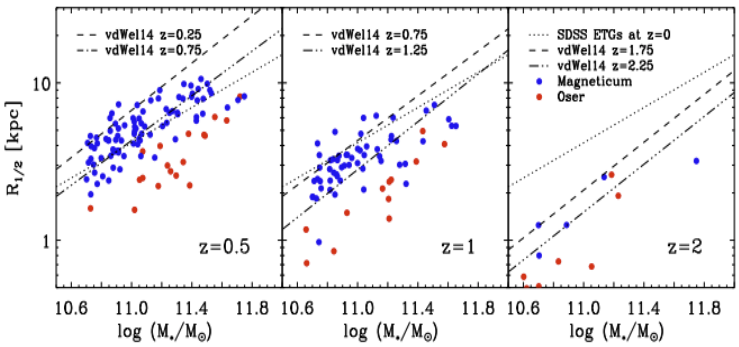
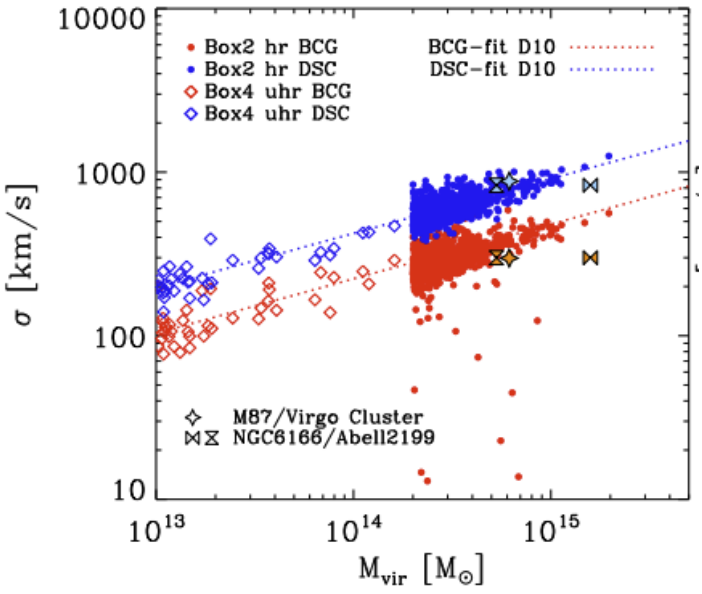


Figure 1. Mass-size relation at $z = 0$ for Magneticum ETGs (blue), Oser ETGs (red) and Wind ETGs (yellow) compared to the mass-size relations for ETGs from the SDSS survey (left panel; Shen et al. 2003, black solid line) and from the GAMA survey (right panel; Baldry et al. 2012, black dotted line). The shaded areas mark the 1σ-range of observations.



Caution this is for the (48 Mpc/h)^3 box !!!!!! How resolution is going to affect this?

Remus 2017:



Lotz+2019:

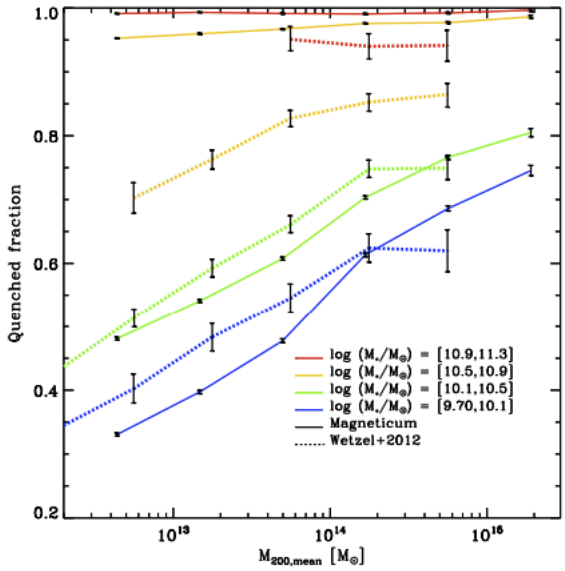


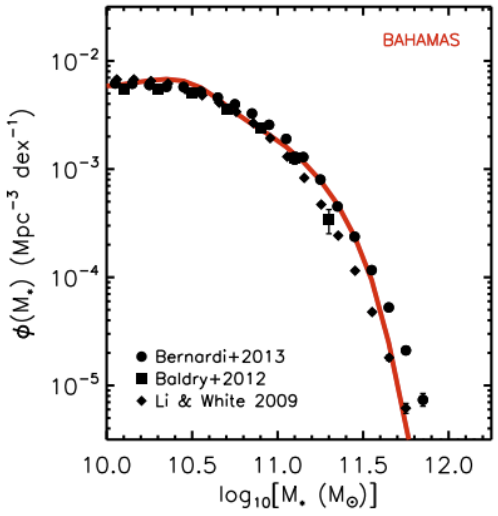
Figure 2. Box2/hr quenched satellite galaxy fractions in dependence of host halo mass, split into four stellar mass bins at $z \sim 0$. Solid lines show the different stellar mass bins from the Magneticum simulation, while the dashed lines show the observations extracted from Wetzel et al. (2012). The Magneticum errors are calculated via bootstrapping.

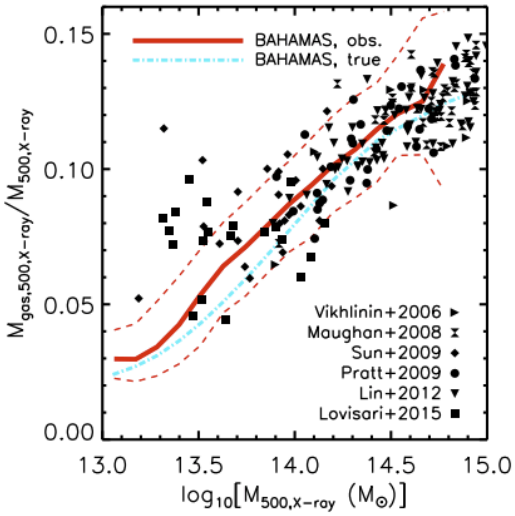
Strong bimodality? quenching is not a result of the environment, but rather a self-regulatory behaviour, i.e. AGN feedback kicking in at a specific stellar mass as dictated by the implemented feedback model.

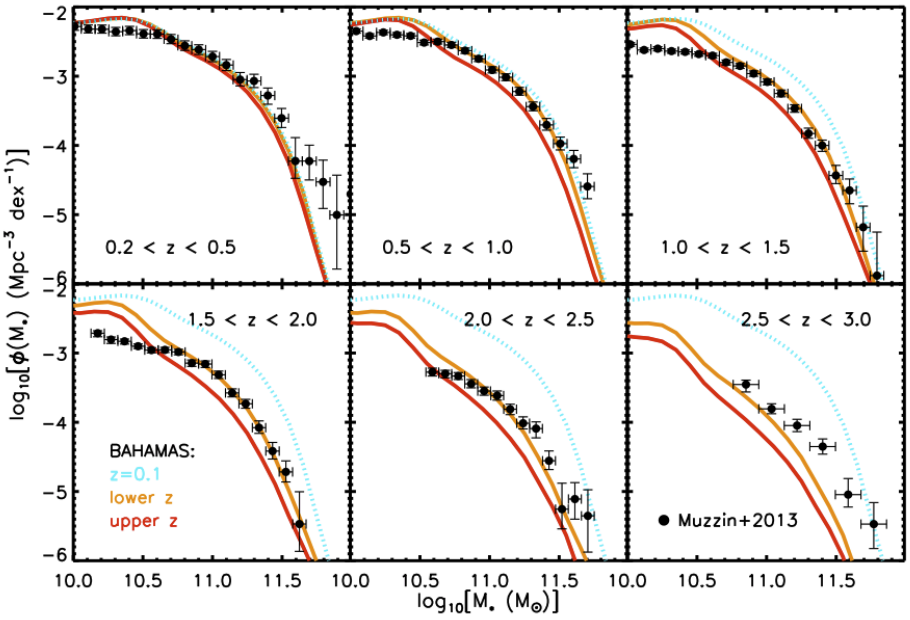
BAHAMAS:

Code: Gadget
Size : (400 Mpc/h)^3
Particle mass resolution: 7.66×10^8 Msun
DM resolution: 3.85 × 10^9 Msun
Spatial resolution: 4 kpc/h
Worse resolution than the others. No sats < 10^10Msun. How does this affect the % of light?

McCarthy et al. 2017:







BAHAMAS vs GAMA : https://arxiv.org/pdf/1712.05463.pdf

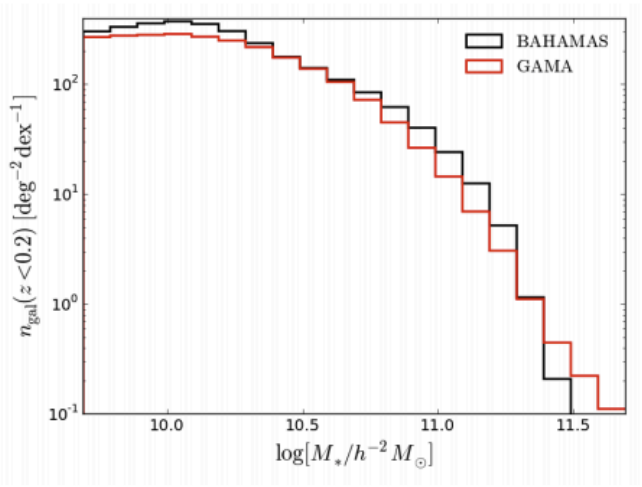


Figure 2. The stellar mass functions of the approximately volume limited galaxy samples from GAMA and BAHAMAS. The simulation feedback models were calibrated to reproduce the present-day stellar mass function in McCarthy et al. (2017).

2020/7/16 Meeting

Summary of simulations above.

Need to contact simulators -> ask for mock observations to LSST depth with LSST filters.
Need to work with simulators -> what depth to ask for / PSF to provide?

How map simulation to observations - depends on smoothing thingies etc. to form mock observations. So can be tricky, particularly for low particle density regions like ICL. Everyone will have different mock obs pipelines.

What characterises best the ICL prediction from simulations in terms of structure and evolution?

Mireia will contact Claudia and Rodrigo - ask if they've made ICL images.
Mireia will contact other simulators regarding their interest.
Can also use Horizon-AGN, through Sugata & Garreth expertise for creating mock-images.

2021/6/17 Meeting

Attending: Mireia Montes, Sarah Brough, Garreth Martin, Brandon Kelly, Joli Jimenz Teja, Gaspar Galaz, Chris Mihos, Cristina Martinez-Lombilla, Rodrigo Canas,

Agenda:

- Welcome to Yolanda! Chebyshev-Fourier functions to measure ICL fractions.
    - Observers to measure ICL?
- Garreth has provided the codes to create the mock images from simulations. We are working on generalizing them.
- We have contacted the simulators. What do we want from them? In terms of mass/redshift of the groups/clusters/products.
    - How do we measure the ICL in simulations? <---- Should be consistent between simulations (or as consistent as possible). What would be the easiest way to separate the ICL from galaxies? Should we leave this up to the simulators?
    - Idealized 2D mock images without noise to see how much ICL we are missing at different SB depths?

List of observers that will measure the ICL:

- Mireia Montes
- Yolanda Jiménez-Teja
- Amael Ellien

- Rossella Ragusa
- Chris Collins ?
- Anthony Gonzalez

List of simulators:

- Garreth Martin (Horizon-AGN)
- Annalisa Pillepich (Illustris/TNG)
- Yannick Bahé (EAGLE/Hydrangea)
- Rodrigo Cañas (300 simulation)

Observations

- Mireia has emailed and heard back from the simulators listed above.
- What ICL fitting skills DO we have in the group?
    - CHEFs ICL estimator, a robust and accurate algorithm free of a priori assumptions
    - DAWIS - Wavelet decomposition? (student working with Florence Durret)--> Mireia to send an email to Amael Ellien
    - Summing luminosity below particular SB limit
    - Fit surface brightness profiles of ellipticals and see what's left over
    - Stacking? (Yuanyuan Zhang)
- Main focus fraction of ICL, but generally interested in amount of ICL

Simulations

- What do we ask simulators to do regarding ICL?
- Not asking simulators to measure ICL from mock images (but are asking them to create those)
- Do we ask each of the simulators how they would measure ICL and ask each simulator
    - E.g. Fixed apertures
    - E.g. Surface brightness limit

- Good to start things simply. E.g. In simulations, all galaxies have measured radii - outside e.g. 3Re = ICL, then what is that in 3D space? And what it is in projected/mock image.
- Unbinding and separating in simulations is hard…
- Mock images - want them to be infinitely deep. Then it is easy to add noise at different levels.
- Range of redshift / mass ? Simple option: z~0, clusters (of a range in mass that is accessible to all the simulations - likely <10^14). Look at evolution later. ~TNG100/Hydrangea (midpoint in cluster mass/resolution).

Mireia to contact simulators next and coordinate with Rodrigo.

2022/1/27 CHALLENGE RESET: EMAIL

Hi All,

I'm hoping to make some significant progress and ideally complete this year, the Rubin Galaxies Science Collaboration's Low Surface Brightness Working Group's Challenge#3: Do observers and simulators measure the same quantity of Intracluster Light (ICL)?

I've added people listed as members of the #lsb-challenge#3 slack channel to the challenge google doc (https://docs.google.com/document/d/1HaRLBpwCH4rxeZktBpcINDAddNqHqPzWEQEVM0aJ_FM/edit) to ensure that I send emails to the correct list of people. Please let me know if you just want to watch what happens in the slack channel and not receive emails!

The reasoning behind this challenge is that ICL measurements to date show significant scatter. Each observer uses their own measurement method and we compare these heterogeneously-obtained results interchangeably. How can we be sure we are measuring what we think we are measuring? The intention of this project is to set the cleanest definition of intracluster light measurement, so that when observers, and simulators, measure total ICL and ICL fraction (including with LSST), we can be confident in the method used, and encourage more future measurements to be made using homogeneous techniques.

We intend to do this by applying the current available observational techniques to mock images from a series of simulations (with large enough box size and adequate resolution to study ICL) and comparing the results obtained with the observational methods with the predictions the simulations make about the amount of ICL in their mock images (with a side question of how dependent the observational measurements are on orientation).

Mireia who has ably led the challenge to this point has identified and contacted key observers and simulators

Simulators:

- Garreth Martin (Horizon-AGN)
- Annalisa Pillepich (Illustris/TNG)
- Yannick Bahé (EAGLE/Hydrangea)
- Rodrigo Cañas (300 simulation)
- Rhea-Silvia Remus and Lucas Kimmig (Magneticum)

Observers:

- Yolanda Jiménez-Teja (CICLE, 2D wavelet-like)
- Amaël Ellien (DAWIS, 2D wavelet-like)

- Anthony Gonzalez (2D fitting - that means BCG + ICL separation with 2 Sersics…actually, no, I don't normally separate BCG+ICL, but you can :P ;))
- Rossella Ragusa (1D fitting to the radial profile of several components)
- Cristina Martínez-Lombilla (2D fitting over PSF-deconvolved BCG; SB cut)
- Mireia Montes (2D fitting; SB cut)
- Lammim Ahad (1D fitting to the profile - both single component fit to the BCG and two-component fit to separate the BCG and ICL)

I have identified key next steps as:

1. Agree simulated definition of ICL
2. Identify timeline for obtaining mock images from other simulations.
3. Identify timeline for observers to run their measurement techniques.
…[Work happens here]…
N. At which stage I intend to bring the data together to make key plots: total observed ICL vs total simulated ICL. Fraction observed ICL vs fraction simulated ICL and lead writing up of project.

My intention is to arrange to meet with the simulators and observers named above in the next few weeks to agree those definitions and timelines with the aim of having regular (weekly/fortnightly?) meetings with that smaller group of people until the necessary mock images and measurements are available.

There is a significant amount (if not total!) overlap in our key observers and simulators with those working on a separate but complementary project with Euclid, led by Nina Hatch. Nina will discuss in that project whether joint meetings might be possible, to reduce meeting overload.

I intend to organise group meetings for the broader challenge group emailed here, interspersed between the more regular simulator/observer meetings, in order for the broader group to have the opportunity to contribute and will also post updates on slack to keep everyone in the loop.

Please email me or reply in the slack thread if anything is unclear or seems unreasonable or unworkable…

2022/2/9 Meeting ICL Squad

Attending: Mireia Montes (ICL), Yolanda Jiménez-Teja, Amael Ellien, Rossella Ragusa (1D light fitting to find separation galaxies/ICL), Anthony Gonzalez (lots of ICL analysis, Garreth Martin (Horizon-AGN,), Annalisa Pillepich (Illustris/TNG), Yannick Bahé (simulator EAGLE/Hydrangea, looking at ICL), Rodrigo Cañas (300 simulation)), Cristina Martinez-Lombilla (2D light fitting to examine ICL)
Apology: Annalisa Pillepich

1. Agree simulated definition of ICL

Yannick: Not easy answer. Separating ICL from satellites, can do well. Is star bound to satellite or part of background. How separate between BCG and ICL? Rodrigo's phase-space separation might be best way? Ultimately no hard fast way between BCG/ICL. Distinction between BCG + ICL. 20-100kpc? Inner parts of BCG do come from stripping of galaxies.

MM: Annalisa's view (through SB & MM) - do we want to separate BCG+ICL ? Is there a point to doing that? Anthony philosophy to retain BCG+ICL?

Rodrigo: Should be on same page: What do we mean by ICL? In cluster - several galaxies with own haloes. Are they counted in the diffuse light? Rodrigo has method, whether gives answers, well we can see. Smooth profile to centre - separating two component.

Yoli: MM question. At some point for many studies, be interested in separating BCG/ICL. To measure ICL evolution is important. Trying to compare observational technique with simulations. If simulations can easily separate satellite galaxies from ICL then can more easily compare the combined BCG+ICL with theoretical as STAGE1, and potentially disentangle ICL as STAGE 2.

Do BCGs have an extended component OR is everything that isn't galaxy == ICL?

MM: Can have several definitions of ICL in simulations? Yannick said Annalisa looks at 30kpc aperture. Rodrigo phase space etc.

Rodrigo: recommend making the different measurements on the different simulations. MM: 3-4 definitions to each sim? Rodrigo has exp on running on diff simulations.

Methods to be applied to each simulation:

1. Annalisa's aperture method
2. Yannick's BCG+ICL (NO SATELLITES ALLOWED)
3. Rodrigo's 6-phase space method
4. Magneticum? SB to chase previous discussions! Used velocities, as detailed as can radially, when get to point when BCG+ICL velocities are different use double-maxwellian [doesn't agree with sersic profile splitting]

2. Identify timeline for obtaining mock images from other simulations.

Garreth has code to convert simulations to mock images. Taken Allison Merritt (2020 paper) method, to smooth distribution of light (from simulations is in particles), made version of that. No dust at the moment. Stellar ages and masses and go through stellar template and gives image. Just need ages and masses to apply to other simulations.

Yannick, dust not treated consistently between sims. So ? Don't expect dust to be strong in ICL.

Halo mass: should aim for similar halo mass system to simulate. 10^14 mass system. WELL-BEHAVED/RELAXED cluster. This mass is safe for Horizon-AGN. Lower mass will be faster to simulate too.

What do observers need from simulation mock images: Wide field to get to decent sky level. Ideally out to 2x virial radius.

Do observers care about background/foreground galaxies? Should we include those in the simulations? Start simple and then likely add at a later stage.

If we want to compare methods - need to compare with exactly same image/same conditions. Then see how foreground/background galaxies affect that measurement.

ACTION ITEMs before next meeting:

- Simulators to prepare mock images of RELAXED 10^14 mass cluster at z~0(ish!). Work with Garreth to convert simulation to mock images in consistent fashion. Discuss via slack in the interim (or email me if difficulties)
- SB to follow up Magneticum.

2022/2/23 Meeting ICL Squad

Next meeting: Wednesday 23rd February at 11pm (Sydney), 9pm (Korea), 1pm (Europe), 7am (East Coast US), 4am (Mexico) using zoom link: https://unsw.zoom.us/j/9215829921

Attendees: Sarah Brough, Cristina, Annalisa, Yannick, Lammim, Mireia, Garreth, Anthony, Yoli
Apologies: Rossella Ragusa, Rhea-Silvia, Lucas Kimmig, Rodrigo Canas

Agenda:

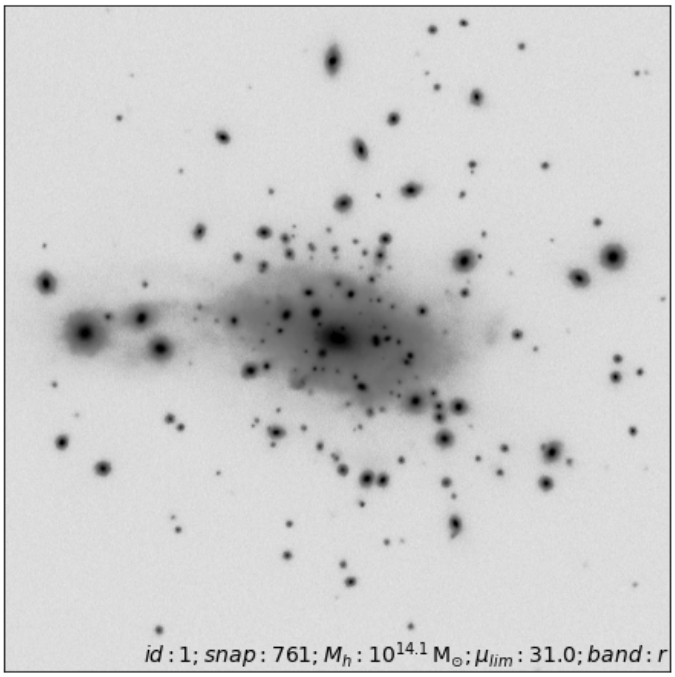
1. Status of / Questions regarding Mock Images (e.g. do we need to / are we using simulations with the ~same resolution?)
2. Update re Magneticum
3. Identify timeline for observers to run their measurement techniques on the mock images
4. Status of plans to measure ICL in the various ways in the various simulations

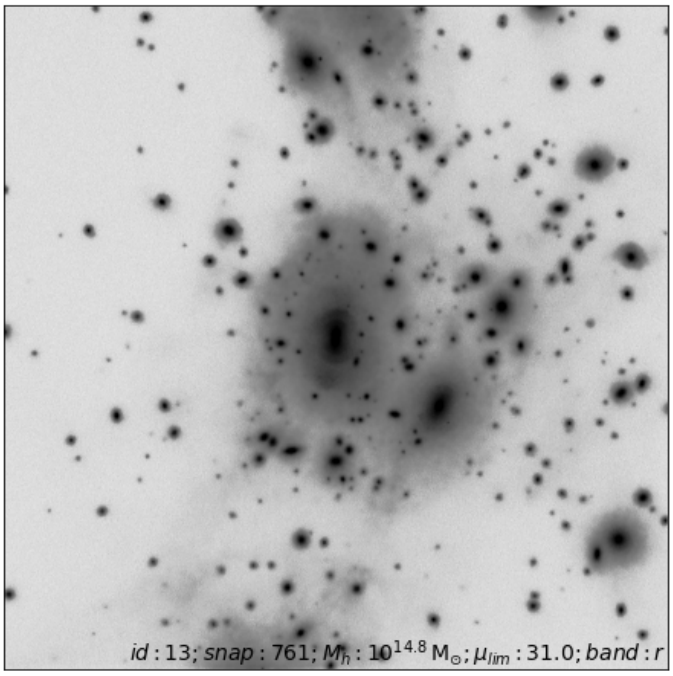
Garreth - The code I wrote to produce smoothed mock images is here. You can download a demo and the code here:
https://www.dropbox.com/s/tyus2r23s91r68w/hz_mock_example.zip?dl=0

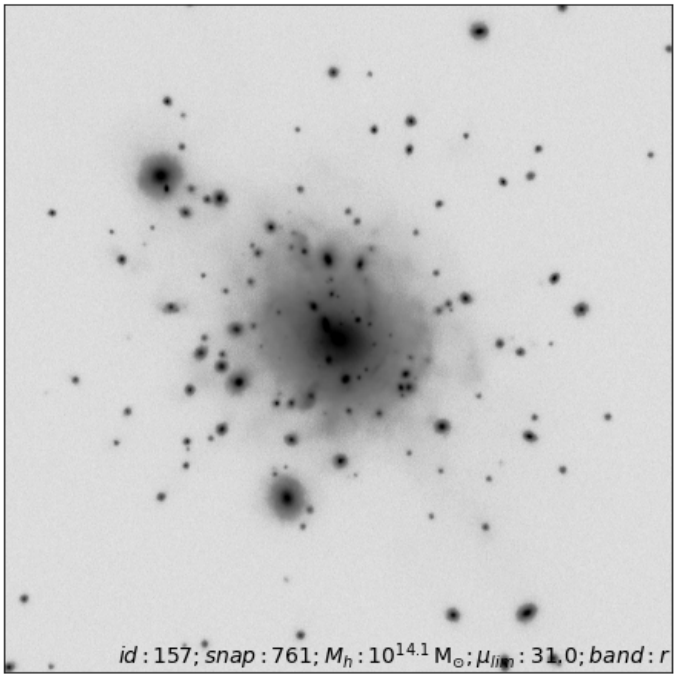
Input units for the particles are proper kpc, solar masses and years, metallicities are non-solar. Output image flux converts to AB magnitudes via m = -2.5*log10(f).

The example code produces mocks of a few Hz-AGN galaxies, and also convolves w/ HSC PSF (from Montes+21) and adds Gaussian noise to simulate a given SB limit.

See below a few Horizon-AGN examples:







1. Mock images

=> Simulators extract cubes/particles and send to Garreth to extract mock images or simulators could use code to extract mack images
=> Mass of simulated cluster 10^14-14.5 in M_200,crit.
=> RELAXED systems, defined by eye
=> Redshift z~0.00, data from all simulations taken at z~0
=> Resolution: ideally stellar particle mass 10^6-10^7 (absolute max 10^8) ~TNG-100 (run without changing model), Horizon-AGN.
=> Method: random projection, what material including volume or FoF when do projection, and what sizes? Just used natural volume selection of 1Mpc cube, but intend to go 2X2Mpc (so can go out to 2r_vir). Integration depth +/-2.5 Mpc for first pass. Extract 5x5x5Mpc Cube, from simulation snapshot at z = 0.
=> Upload cubes to Garreth dropbox for him to run mock image making process

What Garreth needs from cubes here:
At final snapshot of the simulation
Volume - 5 Mpc x 5 Mpc x 5 Mpc (proper)

Positions - kpc (proper) (3 x N)
Central co-ordinate (same units as position)
Particle mass - solar mass (initial particle mass, as the SSP templates include mass loss, if they can differ slightly, the using the same average initial mass for every particle is fine.)
Metallicity (Z, non-solar mass fraction)
Age - years
Velocity - km / s (3 X N)
+ M200 halo mass - Msun
+ Central galaxy stellar mass - Msun

Not too important, but it would be easiest for me if you save the datasets with the following labels in quotes below (this is the code I use to read in the data currently):

```
gid = f['galaxy_id'][()]
snapshot = f['snapshot_id'][()]
mhalo = np.log10(f['halo_mass_msun'][()])
mgal = np.log10(f['galaxy_mass_msun'][()])
X_c = f['X_c_kpc'][()]
X = f['X_kpc'][()]
mass = f['initial_mass_msun'][()]
met = f['metallicity'][()]
age = f['age_years'][()]
velocity = f['velocity_kms']
```

If possible - please produce individual files for each object saved in .hdf5 format with the following naming convention <id>_<snapshot>_<simulation_name>.hdf5
Then please archive / compress them together and upload here:
https://www.dropbox.com/request/eWUitXnHmMD4LAqojX06

Garreth has run mock image making process for Horizon-AGN
Yannick would prefer to run mock image making process for C-EAGLE
Lucas will send through Magneticum to Garreth for mock image making process
Annalisa will send through to Garreth for mock image making process to ensure consistency of mock process.

Postage stamp images + code to produce .fits files with a given limiting surface brightness for all the simulations processed so far can be found here:
https://www.dropbox.com/sh/dj5m55jsf75t4mh/AADLS_WUb_BkjjlwiSXE2WG2a?dl=0

ACTION ITEM => First set mock images will be available for observers before next meeting

Mock images have HSC PSF applied that will need to be deconvolved by observers!

2. Discussions with Magneticum Team - Rhea-Silvia and Lucas

- 10^14 solar mass cluster as small as Magneticum goes.
- Halo == M200?? Dependence on elongation if not relaxed?
- Will send cube to Garreth for mock-image creation within next 2 weeks.
- Questions for ICL Squad meeting: did Rodrigo run velociraptor on Magneticum, yes but with older code, Rodrigo to contact Rhea-Silvia re running newer code on Magneticum. What box size/resolution everyone using? See above.

3. Observational Measurements

Observers to measure:

- Quantity of ICL (total luminosity, Mass)
- Quantity of BCG+ICL (total luminosity, Mass)
- Fraction of ICL Luminosity vs total stellar component in cluster within 1Mpc radius
- Fraction of BCG+ICL Luminosity vs total stellar component in cluster within 1Mpc radius

Video of meeting available:
https://www.dropbox.com/s/8v5sos50vwio4hb/ICLSquad_230222.mp4?dl=0

Next meeting will be organised for roughly 2 weeks from now, via
https://doodle.com/poll/ek2am5zth4x4hw7q?utm_source=poll&utm_medium=link
Most responses: Wednesday 9th March at 11pm (Sydney), 9pm (Korea), 1pm (Europe), 7am (East Coast US), 4am (Mexico) using zoom link: https://unsw.zoom.us/j/9215829921

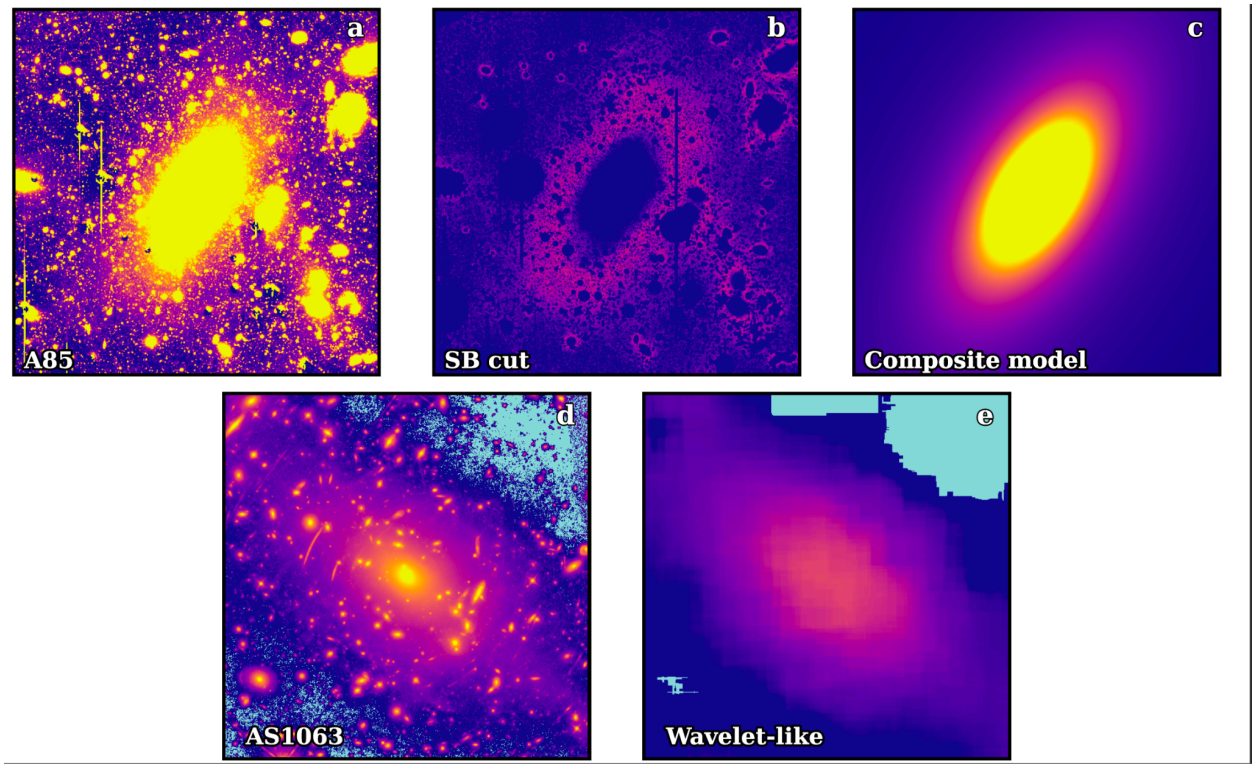


Figure from Mireia's upcoming ICL review paper

2022/03/09 Meeting ICL Squad

Attendees: Sarah Brough, Anthony, Rossella, Rhea-Silvia, Cristina, Garreth, Lucas, Lammim, Amael, Yoli, Yannick, Annalisa
Apologies: Mireia, Rodrigo

Agenda:

1. Status of / Questions regarding Mock Images

    a. Garreth has put simulations processed in dropbox and shows pngs at different limiting surface brightnesses are above. 3 different orientations xy,yz,zx?
    b. Ipython file in dropbox, can put in limiting surface brightness (Adds Gaussian noise to image) and will produce final fits file in r-band. **https://www.dropbox.com/sh/dj5m55jsf75t4mh/AADLS_WUb_BkjjlwiSXE2WG2a?dl=0**
    c. HYDRANGEA to come.
    d. FYI from https://smtn-016.lsst.io/: LSST 10yr depth r-band limiting SB 30.3 mag/arcsec^2 [u~29.4 g~30.3 r~30.3 i~29.7 z~28.9 y~28.1 median 3-sigma surface brightness limits for a 10x10 arcsec area in our current baseline survey strategy after 10 years]

e. Observers - seem like good idea and start with LSST 10yr SB depth and r-band. Maybe in the future also measure 28 mag/arcsec^2 to compare to previous measurements.
f. Right now mock images for: Horizon, TNG100, 1 from Magneticum, and Hydrangea files to process. Need Three Hundred Simulations too.
g. Magneticum in this box 5 clusters at this mass. 1 relaxed, sent through, 2 definitely not relaxed. In bigger box size, easier to find more relaxed clusters. Bigger box size, slightly different way of calculating than other simulations, ~ 2x10^7Mdot gas particles. Mostly looking at collisionless process so star particles more important, and better not to just have outlier in mass… So yes, decided to keep 1 cluster at higher resolution and explore bigger box.
h. SB to talk to Rodrigo about 300 simulation cubes.

2. Identify timeline for observers to run their measurement techniques on the mock images
    a. Observer Q re mock images:
        i. Noise? Yes, added in python from Javier Roman's paper which gives noise/pixel given that SB limit: Roman+2020 https://arxiv.org/pdf/1907.00978.pdf Appendix A
        ii. Mock images ARE Convolved with Hyper-Suprime Cam g-band PSF (from Mireia et al. 2021).
        iii. Pixel size: 1kpc per " and 5XMpc cube
        iv. How many clusters should observers look at? [ACTION ITEM: SB to look at pngs in dropbox to define a relaxed cluster per simulation] Once observational methods are working on 1 cluster, let's start with 1 cluster x per each of 5 simulations per 3 orientations. Hope to expand sample further for more statistics but we shall see how we go.
        v. Other galaxy contamination? Some, but only within Mpc box around cluster. Mostly only cluster galaxies there. Total luminosity to 1Mpc radius so very likely only cluster members there.
        vi. [ACTION ITEM OBSERVERS by next meeting: Take 1 relaxed cluster image from dropbox from Monday 14th March, use Python notebook in dropbox (make_mocks…) which will create a fits file, applying SB limit. and try measuring ICL amount and fraction. Raise questions in slack and/or at next meeting]

3. Methods to be applied to each simulation.

   Status of plans to measure ICL in the various ways in the various simulations:
   Simulators to apply to their own simulations [bar velociraptor to be applied by Rodrigo]:

   [Eagle, Hydrangea all use Subfind. Magneticum can use Subfind or other]

   Annalisa's -> after excising satellites [as carefully as possible, via individual particles/direct removal. Agree to remove particles that we think are bound to satellite…], decided where BCG ends and ICL starts on radial/spherical aperture. As complicated to separate, might not be such a difference, just measure stellar mass in apertures 30, 50, 100kpc. OUTER RADIUS is 1MPC
   https://academic.oup.com/mnras/article/475/1/648/4683271

   Yannick's -> Similar to Annalisa ***but without inner cut***, Yannick calculated everything together (again, NO SATELLITES ALLOWED). OUTER RADIUS is 1MPC

   Rodrigo's 6-phase space method -> SB to talk to Rodrigo about running on each of the simulations [what need?]

   Magneticum -> Use velocities, as detailed as can radially, when get to point when BCG+ICL velocities are different use double-maxwellian to separate.

4. Any Other Business

5. Next meeting: Wednesday 23rd March at 11pm (Sydney), 9pm (Korea), 1pm (Europe), CHECK 7am (East Coast US), 4am (Mexico) using zoom link: https://unsw.zoom.us/j/9215829921 East Coast US clocks will change before but no-one else. We will doodle for meeting time afterwards as everyone else's clocks start to change.

Relaxed Clusters

[SB 14/3/22]

I've visually-inspected the png files in the dropbox linked above to identify 'relaxed' clusters. Judging on the mu=30.0 images [SB 23/6/22: Should have done mu_r=30.3!] and each of the xy, yz, xz directions. The key is that ? = elongated in 1 axis and/or streams. X = elongated, two large BCGs or in-falling group etc. No key suggests that the system is ~relaxed.

I indicate the cluster to start on for each simulation with **. Start with the xy dimension. We will eventually do at least 1 cluster from each simulation in each of the 3 dimensions, and if

the data are easy to work with then multiple clusters per simulation. Happy to answer questions about this selection, and questions re the simulations are best directed to others.

Horizon-AGN
00761_0000001_30.00_0.05_r_xy_4Mpc.png ?
00761_0000009_30.00_0.05_r_xy_4Mpc.png ? (shells)
00761_0000046_30.00_0.05_r_xy_4Mpc.png X
00761_0000048_30.00_0.05_r_xy_4Mpc.png **
00761_0000049_30.00_0.05_r_xy_4Mpc.png ?
00761_0000071_30.00_0.05_r_xy_4Mpc.png X
00761_0000078_30.00_0.05_r_xy_4Mpc.png
00761_0000132_30.00_0.05_r_xy_4Mpc.png ?
00761_0000137_30.00_0.05_r_xy_4Mpc.png X
00761_0000157_30.00_0.05_r_xy_4Mpc.png
00761_0000174_30.00_0.05_r_xy_4Mpc.png X
00761_0000183_30.00_0.05_r_xy_4Mpc.png X

Hydrangea
00029_0000760_30.00_0.05_r_xy_4Mpc.png ?
00029_1000000006_30.00_0.05_r_xy_4Mpc.png X
00029_2000000338_30.00_0.05_r_xy_4Mpc.png
00029_3000000058_30.00_0.05_r_xy_4Mpc.png ?
00029_3000000213_30.00_0.05_r_xy_4Mpc.png**
00029_4000000020_30.00_0.05_r_xy_4Mpc.png X
00029_5000000086_30.00_0.05_r_xy_4Mpc.png X
00029_6000000000_30.00_0.05_r_xy_4Mpc.png ?
00029_7000000087_30.00_0.05_r_xy_4Mpc.png
00029_8000000075_30.00_0.05_r_xy_4Mpc.png X
00029_9000000047_30.00_0.05_r_xy_4Mpc.png
00029_11000000299_30.00_0.05_r_xy_4Mpc.png
00029_14000002727_30.00_0.05_r_xy_4Mpc.png
00029_15000000353_30.00_0.05_r_xy_4Mpc.png
00029_16000000061_30.00_0.05_r_xy_4Mpc.png X
00029_16000000294_30.00_0.05_r_xy_4Mpc.png
00029_16000000360_30.00_0.05_r_xy_4Mpc.png X
00029_16000000360_30.00_0.05_r_xy_4Mpc.png X
00029_21000003193_30.00_0.05_r_xy_4Mpc.png X
00029_21000003550_30.00_0.05_r_xy_4Mpc.png X
00029_22000000116_30.00_0.05_r_xy_4Mpc.png
00029_22000000961_30.00_0.05_r_xy_4Mpc.png X
00029_22000001112_30.00_0.05_r_xy_4Mpc.png X

00029_22000002675_30.00_0.05_r_xy_4Mpc.png X
00029_24000000210_30.00_0.05_r_xy_4Mpc.png ? Shells
00029_25000001227_30.00_0.05_r_xy_4Mpc.png X
00029_28000035296_30.00_0.05_r_xy_4Mpc.png

Magneticum:
00031_0002033_30.00_0.05_r_xy_4Mpc.png ?
00031_0002114_30.00_0.05_r_xy_4Mpc.png**
00031_0002140_30.00_0.05_r_xy_4Mpc.png ?
00136_0000002_30.00_0.05_r_xy_4Mpc.png

TNG-100
00099_0000003_30.00_0.05_r_xy_4Mpc.png**
00099_0000004_30.00_0.05_r_xy_4Mpc.png ?
00099_0000005_30.00_0.05_r_xy_4Mpc.png X
00099_0000006_30.00_0.05_r_xy_4Mpc.png
00099_0000008_30.00_0.05_r_xy_4Mpc.png X
00099_0000009_30.00_0.05_r_xy_4Mpc.png X
00099_0000010_30.00_0.05_r_xy_4Mpc.png
00099_0000011_30.00_0.05_r_xy_4Mpc.png X
00099_0000014_30.00_0.05_r_xy_4Mpc.png ?
00099_0000015_30.00_0.05_r_xy_4Mpc.png ?
00099_0000017_30.00_0.05_r_xy_4Mpc.png ? (shells!) (edited)

Clusters to start:
Horizon-AGN
00761_0000048_30.00_0.05_r_xy_4Mpc.png **
Hydrangea
00029_3000000213_30.00_0.05_r_xy_4Mpc.png**
Magneticum
00031_0002114_30.00_0.05_r_xy_4Mpc.png**
TNG-100
00099_0000003_30.00_0.05_r_xy_4Mpc.png**

2022/03/23 Meeting ICL Squad

Attendees: Sarah Brough, Rossella, Rhea-Silvia, Cristina, Lucas, Lammim, Amael, Yannick, Rodrigo, Garreth, Anthony, Mireia, Nina
Apologies: Annalisa, Yoli

Agenda:

1. Status of observational measurements on mock images and questions
    a. Rodrigo has discussed with Garreth as need to figure a thing out about the initial mass of the stars
    b. Amael - Models every source in image, break up into little pieces, reconstruct galaxy or ICL bits. Automatic. Took 1 simulated cluster. Picked first of Horizon clusters. Took 2 directions. Rebinned by arbitrary factor (maybe 8) to have image <3000x3000pix as too many pixels. In one direction lots of features. Fraction 15/16% out to 1Mpc radius. SB limit. 6 cores, able to process in 14-15hours. Can put fits files in dropbox. Q. Use wavelet analysis, but can still see in ICL shapes of galaxies? Almost never perfect, some galaxy contamination. Each set of images needs its own refinement. Algorithm designed to process real images, and can capture non-linear features too.
    c. Cristina - large image, not well masked at the moment but the script to get the ICL fraction is working on the mock image. Seems to work faster if dividing the image in patches (or rebinning). Worked on a Horizon-AGN relaxed cluster 00761_0000048_30.00_0.05_r_xy_4Mpc (lim sb = 30). Need PSF to deconvolve and model the BCG (already in the dropbox - thank you Gareth!).
    d. Mireia - pass
    e. Anthony - pass
    f. Lammim - image size should not be a problem for the pipeline. Excel sheet can add in calculations.
    g. Rossella (internet problems) - https://drive.google.com/file/d/1imn5ubVL7BOd-tmDyS7a2S4uIoMtArA_/view
    h. ACTION Garreth-set up dropbox for 'observed' fits files. Done- https://www.dropbox.com/scl/fo/bt2mjwa6f2nhxzyzk0onw/h?dl=0&rlkey=axnjtebivzj6wpslc0w1ujxtt
    i. ACTION: Ideally need PSF to deconvolve. Check example_code/templates/psf_g-band.fits in the dropbox folder
    j. Q: Should we rebin? What is pixel size? It is Rubin size - 0.2". Doesn't hurt to rebin to FWHM (~0.7-0.8", HSC resolution. Rubin predicted to be similar). This can be algorithm dependent, maintain the technique you would use on real data.
    k. Q: re very small units. The images have no zeropoint. Convert to mag directly by -2.5log(counts).

2. Status of ICL measurements on simulations and questions
    a. Rhea-Silvia - for Magneticum [1 cluster from Box4 _test, Box2B, both are last snapshot], went through Annalisa/Yannick methods. Can do for R-S own method.
    b. ACTION: SB to make google sheet for data to go in! Would it be better to do it blind? I worry that it might impact people seeing others fractions. ID. Position. XXX

       https://docs.google.com/spreadsheets/d/1KkfhI15eEq-9ZEKLxgGgtK1px_LSeDT

KRVbx4LWjU8Q/edit#gid=0

c. For velociraptor: Rodrigo just needs access to the server/supercomputer where the simulations are stored. “I still have access to the servers where Hydrangea and Magneticum are stored. This includes TNG as I have access to a public copy of the z=0 snapshot. I don't have access to Horizon anymore, the old server is no longer in use and I haven't requested access to the new one yet. By the end of the week I can have the outputs of the new Velociraptor version of at least Hydrangea, TNG and Magneticum.”
d. Do we have the ID or property list of the clusters used for TNG, Magneticum, Horizon and EAGLE? This would make it easier to synthesize the information rather than sharing the catalog of the entire volumes. Needs coordinates of centre of clusters.
e. Yannick - looked at Hydrangea. Has looked at fractions using Annalisa/Yannick methods. Just needs some time to run Rhea-Silvia’s method. Should have for next meeting.
f. Annalisa - pass.
g. Garreth - Methods to be applied: Annalisa/Yannick (counting everything that isn’t satellite), Rhea-Silvia’s method which uses velocity to separate. Rodrigo will run Velociraptor separately [methods are described in more detail in minutes of meeting 9/3/22]. Use simulation’s native AdaptaHOP structure finder for this effort.
h. Rodrigo to keep all information. Interested to know which particles flagged with different components. HDF5 format please

3. Nina - Anthony and Amael in Euclid group. Not simulating ICL from proper models. Simulating in images assuming sersic profile. Aim is to see how WELL detect ICL in Euclid images. Same q re binning Euclid data - too much of it :)

4. Any Other Business?
    a. Marini paper? Not so relevant - have trained machine learning code to FIND ICL in observations, based on simulation data. https://ui.adsabs.harvard.edu/abs/2022arXiv220303360M/abstract

5. I will doodle the next meeting as Europe and Australia will change their timezones in the next 2 weeks.
   Next Meeting Tuesday 5th April 10pm Australia. Check https://doodle.com/meeting/organize/id/QdJooEJe for your timezone. We will meet via this zoom https://unsw.zoom.us/j/9215829921
6.

PSF: psf file is in misc/ICL_mocks/example_code/templates Note - the pixel scale of the PSF file is from HSC (0.168 arcsec), so you need to first rescale to 0.2 arcsec for the Rubin mocks.

2022/04/05 Meeting ICL Squad

Attendees: Sarah, Lammim, Rossella, Rhea-Silvia, Lucas, Yannick, Mireia, Anthony, Nina, Amael
Apologies: Cristina. Garreth. Rodrigo. Yolanda

Agenda:

1. News
    a. Yolanda's new baby - CONGRATULATIONS! —> THANK YOU!!! Hopefully, I will be able to attend the next meeting! :-D
    b. Rodrigo's new job

2. Status of observational measurements on mock images and questions
    a. [discuss blinding results to prevent biasing - spreadsheet has tab per observer. Observers NOT TO LOOK AT OTHER TABS. If feel unable to not look, please
    b. Anthony - no time yet, looking forward to end of semester 2.5 weeks away :)
    c. Lammim - size is an issue, code quite slow. Masking is proving tricky. SExtractor - if change range of image, extended satellites not masked. And runs slow so slow to fix. Will reduce cube down to radius of interest to help speed up. Q re PSF seems smaller than should be 0.4 vs 1? Action: Mireia will check: MM - It is one!! But It is in the 2D PSF images, depending on what you are doing it might need re-scaling.
    d. Mireia - working with data yesterday. Starting to get numbers. Finding images large to work with.
    e. Amael - working on images. Working on tuning algorithm. No results just yet. Working on each chosen cluster in each simulation. Still rebinning by factor~8 so resolution larger.
    f. Rossella - no problem with data. Will stick with luminosity for ICL fractions. 1D decomposition into 3 components. Have run for 1 direction of 1 cluster in each of simulations. Need to do same estimates in other directions.
    g. Cristina - sorry, I couldn't attend! - Same issues as others as images are very large so masking is painfully slow. Playing with binning, patch sizes and also parallel computing to speed up and now is much better. Working on improving the masks and also on tuning algorithm. No final results just yet.

3. Status of ICL measurements on simulations and questions
    a. I see aperture measurements for Hydrangea and Magneticum in the spreadsheet :)

b. Rhea-Silvia - fractions need to be edited to include satellites. Haven't run own method on these particular simulations, will do in next week.
c. Yannick - q re double-maxwellian. Do fit for each of apertures or for whole thing? [Rhea-Silvia, doesn't fit for ~20% clusters]. Subfind central subbody, find all stars. Yannick will give a try.

4. Any Other Business?
    a. Rhea-Silvia curious if different magneticum simulation box mock images change observers effort. ACTION Observers: if possible please look at Magneticum clusters from Box4 AND Box2b and let her know at our next meeting.
    b. Amael pointed out the **previously chosen TNG-100 cluster (#3) has an infalling group at large radii, so we've moved to chosen cluster TNG-100 #6**

5. Next Meeting Tues 19th April 10pm Australia, 8am US East Coast, 1pm UK, 2pm Europe, https://unsw.zoom.us/j/9215829921

2022/05/03 Meeting ICL Squad

Attendees: Sarah, Garreth, Rossella, Lammim, Amael, Anthony, Nina.
Apologies: Cristina, Rhea-Silvia, Annalisa [Mireia likely late]

1. Status of observational measurements on mock images and questions

    a. Amael measurements for all simulated clusters but TNG. TNG need different tuning and hasn't had time yet. Other 3 simulations same tuning worked. TNG has lots of sources - maybe star-forming regions/globular clusters makes it hard to classify… Main information for separation ICL with galaxies is size and spatial position. But if have lots of sources very close it messes up the classification. Able to run all clusters with same parameters. Results sometimes in mis-classifies/mistakes. Some clusters under different angles, classification mistakes, sometimes different fractions, sometimes BCG in different angle associated with different galaxy. Uncertainties? Not sure how to calculate uncertainties just yet. Means 1 month to TNG.
    b. Anthony: classes done! Should be able to get everything run on month timescale. Might try and play with noisechisel as seems to work really nicely on Euclid.
    c. Update from Cristina (sorry I'm on leave until tomorrow 4th May): Working with a relaxed Horizon-AGN cluster in the xy orientation. Tests on the masks, on the BCG+ICL fraction, and on the ICL fraction with sb cut at 26 mag/arcsec^2. Working well and not that slow now with image cutouts of R=2 Mpc, binning 2x2, and parallelising the masking process by splitting the images in smaller regions and running all of them simultaneously. Starting to apply masks to the relaxed

clusters of other simulations. I have been on leave some days in the last few weeks (+ a conference and other projects), so haven't worked too much on this but I will have some flux and fraction measurements for the next meeting. No Qs so far.

d. Lammim: Horizon-AGN, Hydrangea & Magneticum recommended clusters in xy, yz, and zx directions. Also having problems with TNG. Because lots of compact sources the masking chunks out a lot of it, including the centre of the cluster. Has needed different input parameters for each cluster so far. Will keep trying TNG, and also run on other clusters in simulations, will find out if can use same set of parameters on different clusters in same simulations? May also try hot/cold type masking process.
e. Mireia: haven't been able to do anything yet. Moving to Spain in 2 weeks. Should be able to make some measurements by 1 month-ish from now.
f. Rossella: All recommended clusters in xy directions, including TNG. Should be able to expand sample out in next month.
g. Yolanda?
h. Can observers try to look at clusters in the 2 different Magneticum boxes?
    i. Amael has and didn't see a difference.

ACTION ALL OBSERVERS: By next meeting in ~1 month please try to have measurements for the YY clusters in each simulation in the 3 directions (xy, yz, zx). If you have more time then add the cluster in the other Magneticum box 4 (all directions), and then include other relaxed clusters (all directions). If you get too stuck with any one system/simulation leave it for discussion at the next meeting. Thank you :)

2. Status of ICL measurements on simulations and questions
    a. Horizon-AGN -> Aperture measures and Rhea-Silvia's velocity separation. Code to do velocity separation shared on slack channel. Code seemed to work fine. Only one cluster didn't converge. ACTION for Rhea-Silvia: might it be possible to see code to see if it also doesn't converge on that system?
    b. Hydrangea -> Aperture measures
    c. Magneticum -> Aperture measures
    d. TNG-100 -
    e. Rodrigo - have not heard back from yet.

ACTION ALL SIMULATORS: By next meeting in ~1 month please try to have aperture and velocity separation measurements for each simulation

3. Any Other Business
    a. Nina - nothing to add. Euclid project at a very similar stage

4. Next Meeting June 8th, 10pm Australia, 8am US East Coast, 1pm UK, 2pm Europe https://unsw.zoom.us/j/9215829921

2022/06/08 Meeting ICL Squad

Attendees: Sarah, Anthony, Rhea-Silvia, Lucas [need to go at 2pm], Garreth, Lammim, Mireia, Yannick, Yoli :), Annalisa, Amael
Apologies: Cristina, Rossella

1. Status of Observational Methods
    a. Cristina: I have the masking codes already running ok for the mock images. I've used a hot/cold/unsharp masking process. I edited the images as follows: cutouts of R=2 Mpc, binning 2x2, counts multiply by a 1e12 factor. I have obtained measurements of the BCG+ICL fraction for the H-AGN 048 cluster in the xy orientation. I also have the ICL fraction obtained from sb cuts at 26 mag/arcsec^2 and 26.5 mag/arcsec^2 for all the selected (YY) clusters in each simulation in the 3 directions and for all the H-AGN relaxed clusters (Y). No major issues so far (apart from the tricky masks in some cases).
    b. Have measures from…
    c. Mireia has SB cuts measurements and will put in spreadsheet soon, before then making 2D measurements.
    d. Images are LARGE because 4Mpc*4Mpc and LSST pixel size. So files are larger than observers have been used to.
    e. Lammim also cutout 2Mpc cylinder but no binning. Have done all YY/Ys will now move onto X/? systems.
    f. Questions about Flux/luminosity of mock images. Anthony just put down fractions. Garreth: Images are in -2.5log(flux) will give AB magnitudes. STICK TO RAW IMAGE FLUX FOR NOW.
    g. Yoli: starting to fill in some of the rows. Started with first 4 clusters. No problem with image size, process OK, but very slow to make models. Aperture measure - Yoli usually measure ICL fraction out to detection limit. Modified to measure within 1Mpc radius. So including noise. And should be circular? Noise cancels so is OK. Anthony using circular apertures for both. Lammim circular for cluster members and doesn't matter so much for ICL.
    h. Note from Garreth: if the image size is a significant annoyance for everyone, would it be appropriate to agree on a common rebinning (e.g. by a factor of 5 since the PSF is ~1 arcsec and the pixels are 0.2 arcsec)?

2. Status of ICL measurements on simulations and questions
    a. For AP and TNG100 measurements, for now, ICL = all mass in given aperture excising satellites and excising gravitationally unbound stars. (SO includes all diffuse stars associated with BCG. BCG is THE galaxy dominating the gravitational centre of the potential well, not always most massive). For MAGNETICUM, using subfind so is the same i.e. ICL == stars assigned to BCG but outside of DEFINED APERTURE. In total mass within 1 Mpc radius, INCLUDES stars in satellites and ALL particles within that

radius. Centre of mass = minimum potential without black holes considered. Simulations find not high % of unbound particles in cluster (~1%?).

b. Q re observers (who often put in grant proposals stating ICL stars not bound to any galaxies in the clusters…) - Anthony, stars not related to satellites. Mireia, velocity increases with radius as go out of BCG. And observe distinct colour changes as go out into ICL. Annalisa: break in radii not necessarily change in formation. Amael: definition - stars that are bound to the cluster gravitational potential, not to BCG, but BCG~95% cluster potential so hard to distinguish. Annalisa predict: more stars in relaxed clusters that aren't bound but will eventually relax and bind to the BCG?
c. Rhea-Silvia: Lucas - testing projection effects. Questioning 2Mpc radius 2D cut by observers as simulation is 3D - cube, so simulators only considering 1Mpc radius SPHERE, but observers end up with 1Mpc radius, 4Mpc length CYLINDER. Consider future simulations with 1Mpc radius, 2 Mpc cylinder? Garreth - easier for simulations to make change? Annalisa… but relies on subfind which makes it harder. SB - we definitely need to consider this, and I will think more about this vs what has been done in simulation vs observation comparisons to date, before our next meeting
d. Annalisa: simulators please add M200crit to column of simulations! DONE

3. Status of Plots… … … …
   a. SB hasn't done it yet. Will start making next week!!

4. Any Other Business
   a. Next Meeting in 2 weeks: June 22nd, 9pm Australia, 7am US East Coast, 12pm UK, 1pm Europe https://unsw.zoom.us/j/9215829921
   a. Few of us will be at Vegas Collaboration Workshop 13-15 July, Naples-ish (SB, Mireia, Cristina, Rossella, Rhea-Silvia, Others?)

2022/06/22 Meeting ICL Squad

Attendees: Sarah, Rossella, Lammim, Yoli, Mireia & Cristina, Lucas, Yannick, Anthony, Annalisa, Rhea-Silvia
Apologies: Amael, Garreth, Nina

Initial Plots (ICL+BCG Frac for single cluster & mass)

I've started making plots… There are some clear labelling/point-type issues that I haven't had time to fix up yet (apologies!)

Figure 1 below: this is for one single cluster (Horizon-AGN 48). The lines show the xy-yz-zx direction for the observational measurements. The X are the series of aperture measures and the red cross is Rhea-Silvia's measure.

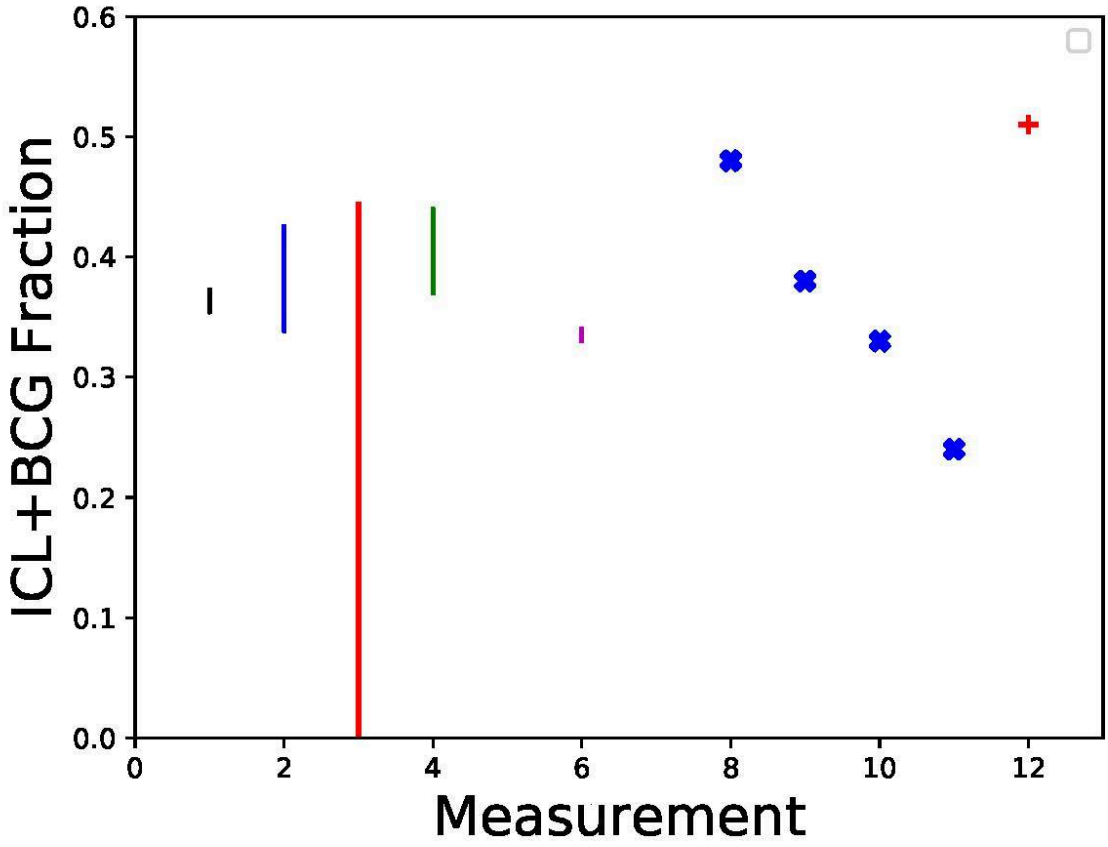
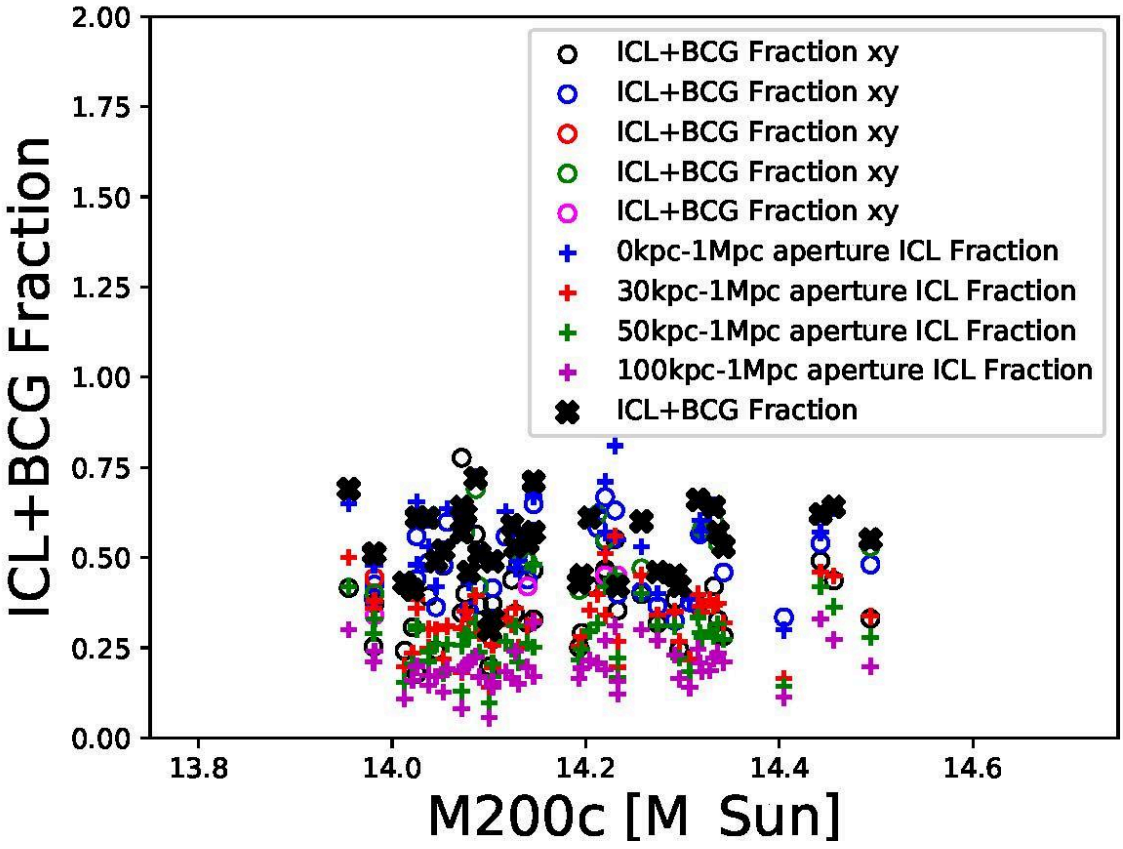


Figure 2 below: ICL+BCG Fractions are as a function of cluster mass, for all measures I've received. The open circles show the observational measurements. The + are the series of aperture measures and the X is Rhea-Silvia's measures.



If comparing with ICL+BCG Fraction then need to only include Aperture 0-1Mpc.

ACTION ITEM: Did Garreth apply the outer 1Mpc limit for Rhea-Silvia's method? As fraction should == Aperture measure 0-1Mpc

For ICL+BCG Fraction Simulated Aperture 0-1Mpc (everything bound by subfind) IS GROUND TRUTH.

ICL+BCG (and ICL) vs Mass binned by mass for each of the observers measurements ? To see if any method has dependence on the mass of the cluster or not. (MM) I'm not seeing that, but can do.

If no mass dependence. Can stack measurements together.

ACTION ITEM: SB to plot N observations histograms of Fraction Observed - Subtract. DONE

ICL fraction comparisons needed too. In this case DIFFERENT SIMS IN GROUND TRUTH.
ACTION ITEM: SB to plot N simulators * N observers histograms of Fraction Observed - Subtract. DONE

What are we seeing? Observers find not totally obvious how stars belong to satellites.

Different directions: Are the different methods consistent with lots of different clusters… Figure 1 - see that for this one cluster 2 methods have less scatter, is that true for all clusters, that those methods have less scatter?

**DEPTH… TEST with new mocks of prototypes.
ACTION ITEM: Garreth can you create extra mocks for the 4 YY clusters with the 2x2x2Mpc cube ?

If no observers find no difference then fine. If significant difference then re-do cubes and measures for all clusters

1. Observer Measures
    a. Amael, everything but TNG [ACTION ITEM: IS TNG possible?]
    b. Anthony, increasing numbers of fractions
    c. Cristina, some clusters - start testing other method on other clusters. Just keep to SB26 measure.
    d. Lammim, some clusters - downloading more data and everything else streamline now.
    e. Mireia, wanting to try some things. Need to put measures into spreadsheet.
    f. Rossella, some clusters. Values for more clusters
    g. Yoli, few ICL fractions (ICL+BCG?). Does model everything out and put model of BCG there, try to separate both. Is faster to just get to ICL+BCG so can do that (thank you!)

2. Simulator Measures
    Aperture measures for all mocks
3. Rhea-Silvia's measures for HORIZON-AGN and Illustris.
    a. Illustris potentially in next 4 weeks
    b. Magneticum running now

4. Any Other Business
    a. Query re SB limit of mock images observers are working with. Should be mu_r~30.3
    ACTION ITEM: SB to create table HERE of key values. DONE

Key Settings

Simulations:

- Mock Code: https://www.dropbox.com/s/tyus2r23s91r68w/hz_mock_example.zip?dl=0
- Mass of simulated cluster 10^14-14.5 in M_200,crit.
- ~RELAXED systems, defined by eye
- Redshift z~0.00, data from all simulations taken at z~0
- Resolution: ideally stellar particle mass 10^6-10^7 (absolute max 10^8) ~TNG-100 (run without changing model), Horizon-AGN.
- Method: used natural volume selection of 1Mpc cube, but intend to go 2X2Mpc (so can go out to 2r_vir). Integration depth +/-2.5 Mpc for first pass. Extract 5x5x5Mpc Cube
- Mock Images: https://www.dropbox.com/sh/dj5m55jsf75t4mh/AADLS_WUb_BkjjlwiSXE2WG2a?dl=0

Observers:

- Fraction of ICL vs total stellar component in cluster **within circular 1Mpc radius**
- Fraction of BCG+ICL vs total stellar component in cluster **within circular 1Mpc radius**
- In mock images with **LSST 10yr SB depth in r-band (30.3 mag arcsec^-2)**
- PSF to deconvolve [example_code/templates/psf_g-band.fits in dropbox folder] = 1” in the 2D PSF images.
- Pixel size is Rubin - 0.2”/pix
- The mock images have no zeropoint. Convert to mag directly by -2.5log(counts).

Spreadsheet:
https://docs.google.com/spreadsheets/d/1KkfhI15eEq-9ZEKLxgGgtK1px_LSeDTKRVbx4LWjU8Q/edit#gid=0

ACTION ITEM: Observers to confirm the SB limit of the mock images they’re using?

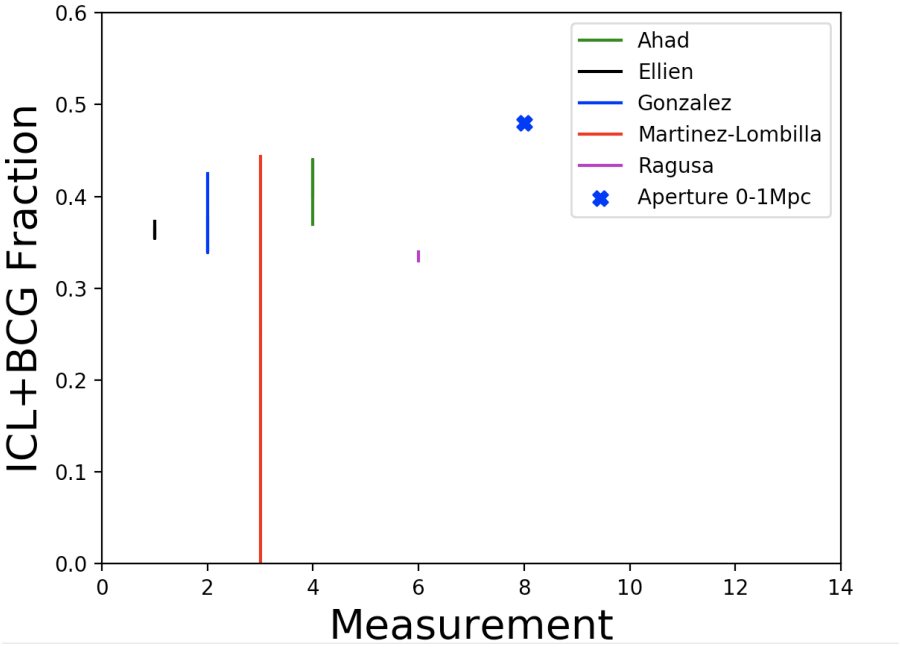
i. Cristina: 30.3
ii. Rossella: 30.3
iii. Mireia: 30.3
iv. *Amael: 30.0 - not limited to 1Mpc radius* (as of 20.07.2022)
v. Lammim: 30.3
vi. *Anthony: 31 - is redoing (as of 10.08.2022)
vii. *Yoli: 30.0 - is redoing (as of 10.08.2022)

b. Next Meeting in July 20th 9pm Australia, 7am US East Coast, 12pm UK, 1pm Europe https://unsw.zoom.us/j/9215829921

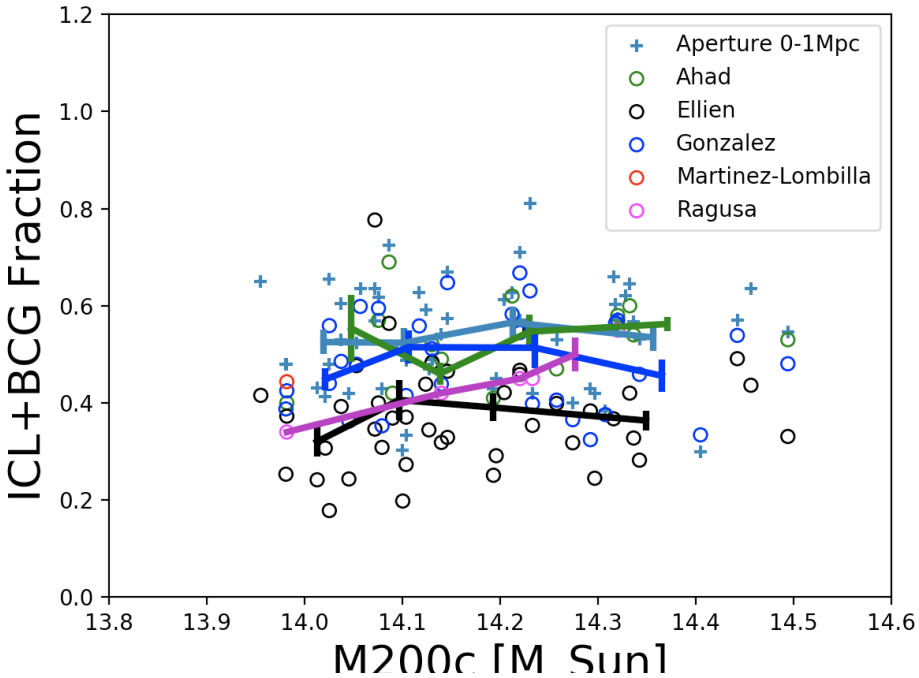
2022/07/13 New Plots

https://matplotlib.org/stable/gallery/color/named_colors.html
https://www.color-hex.com/

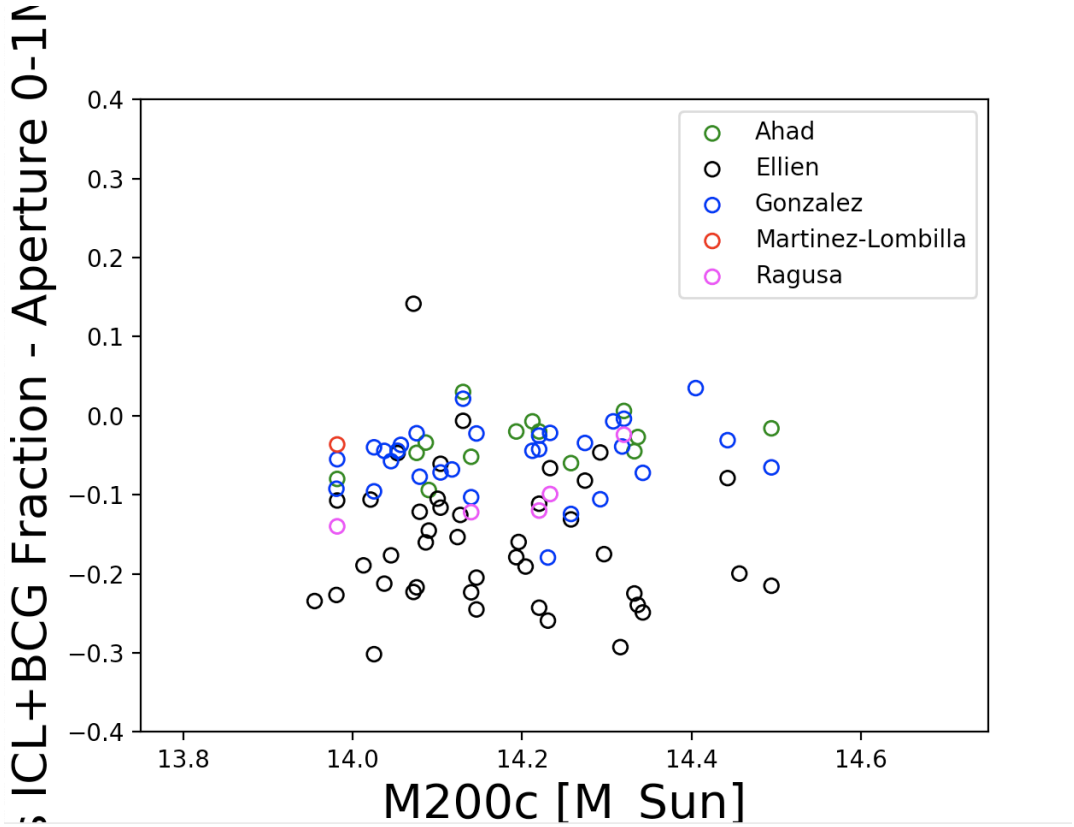
1. **Figure** below: Updated OBS ICL+BCG Fraction for single cluster. Errors are different projections.



2. **Figure** below: Updated OBS ICL+BCG Fraction (xy projection) vs cluster mass with mean values per cluster mass bin. Here are measurements from xxx simulated clusters, from a variety of simulations. SB to indicate different simulations [Rossella, we see mass trend but there are only a handful of points] - CODE UPDATED 22/8 with DIFFERENT SIMS (FIX COLOURS!).



3. Figure below: Difference OBS ICL+BCG Fraction (xy projection) - Aperture 0-1Mpc per cluster mass - notice observed measures generally smaller than simulated [SB to add 0 line and fix caption size - CODE UPDATED 22/8, consider how to mark different simulations] Discussion - Amael's methods generally smaller than others. How BCG+ICL separation made? At the moment not using astrophysical priors to do that. Separation based on wavelet scale. Value of separation varies. At the moment using middle value. Not an existing paper yet, still working on separation value and can do that here comparing to simulations. E.g. 26.5 mag arcsec^-2. Can produce measures varying fractions between ICL and BCG. Suggestion - either come up with/use fiducial or show maximum? Can in Discussion then discuss tunable options. Limiting SB



4 Figure below: OBS ICL+BCG Fraction(xy projection) - Aperture 0-1Mpc Histogram.
Discussion - comparing simulated mass fraction to observed luminosity fraction. Is that OK? Probably not. Observers only have one band r-band. Garreth uses Bruzual & Charlot template to go from particle data to r-band luminosity, doesn't assume . A mass loss is assumed for stars in simulation. Mass fraction should be lower than luminosity fraction.
Add section -> describes how to forward model into observers space, then simulators can calculate luminosity fractions. Garreth to add that section to the overleaf document (thank you, Garreth) for more direct comparison.
[Paper Rudick et al. 2005, compare observers -> simulators, also find observers find lower fractions than simulators]

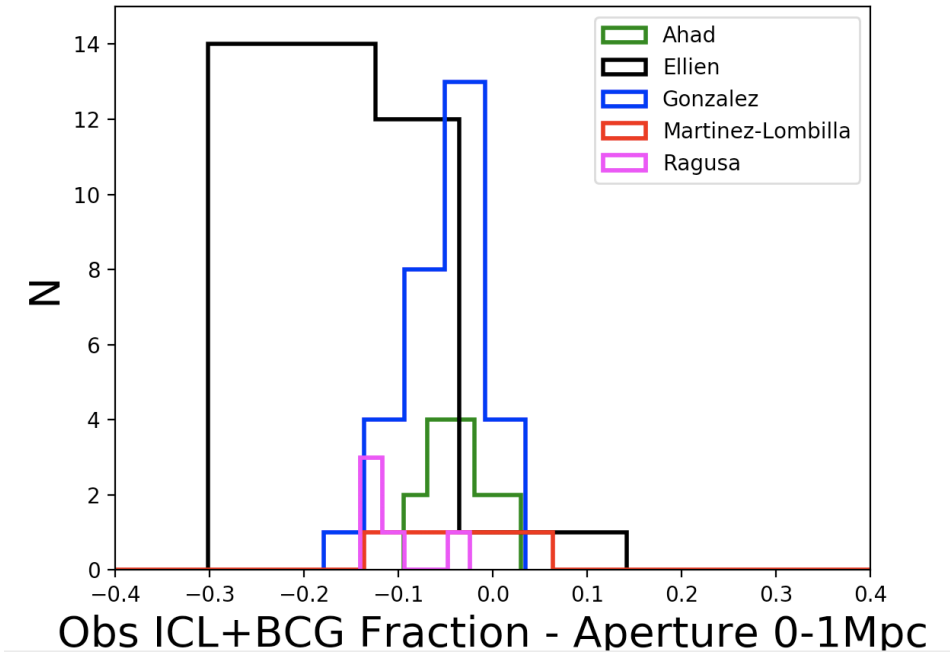


Figure 5 below: OBS ICL Fraction (xy projection) vs cluster mass. Notice kinematic measures are significantly larger [rename as kinematic and separate plots with kinematic vs aperture simulated measures. Indicate different simulations CODE UPDATED 22/8]

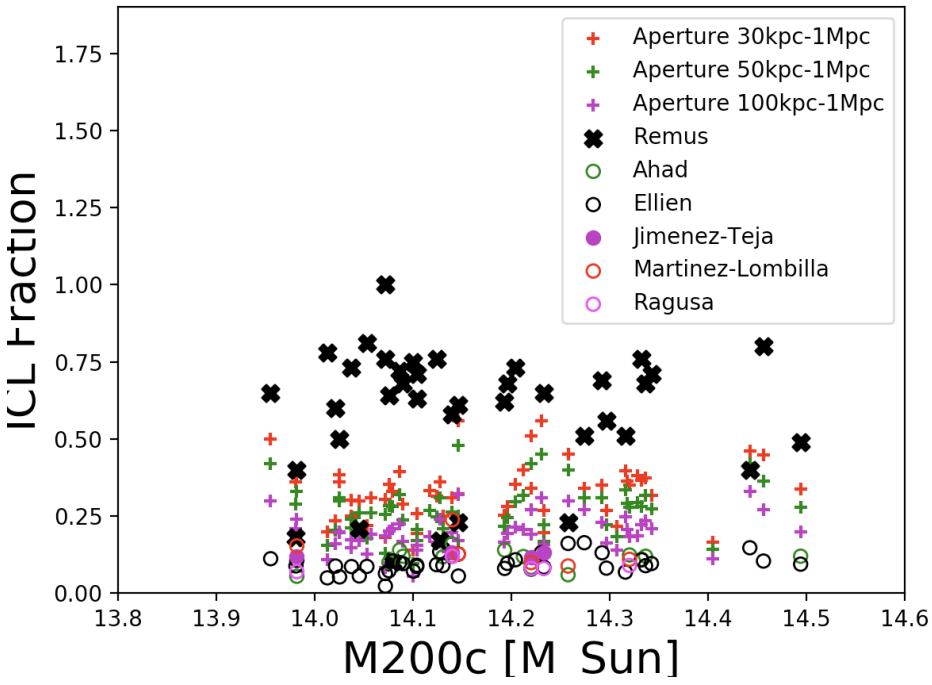
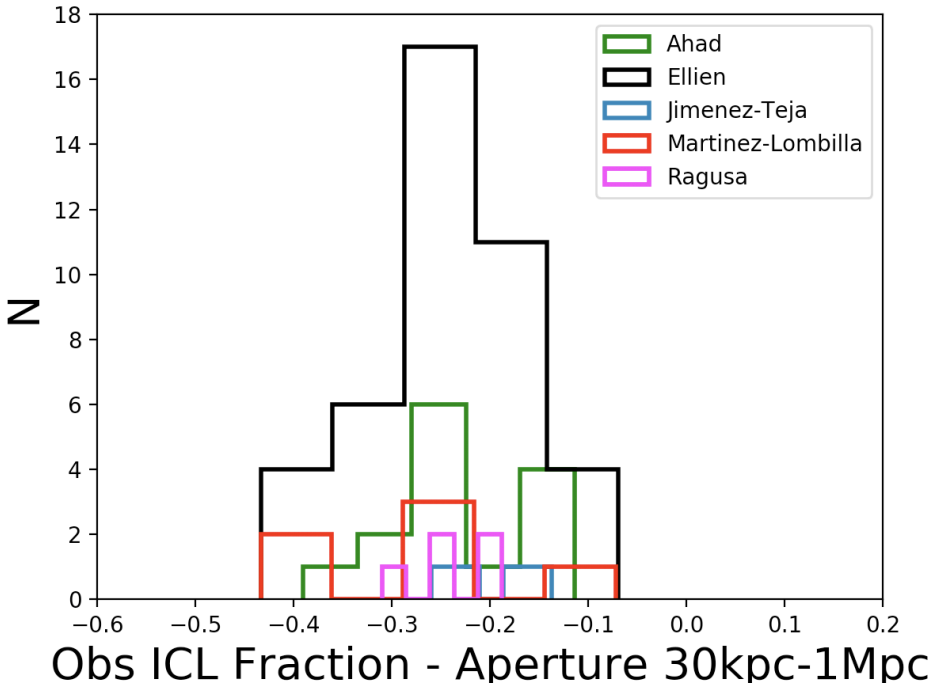
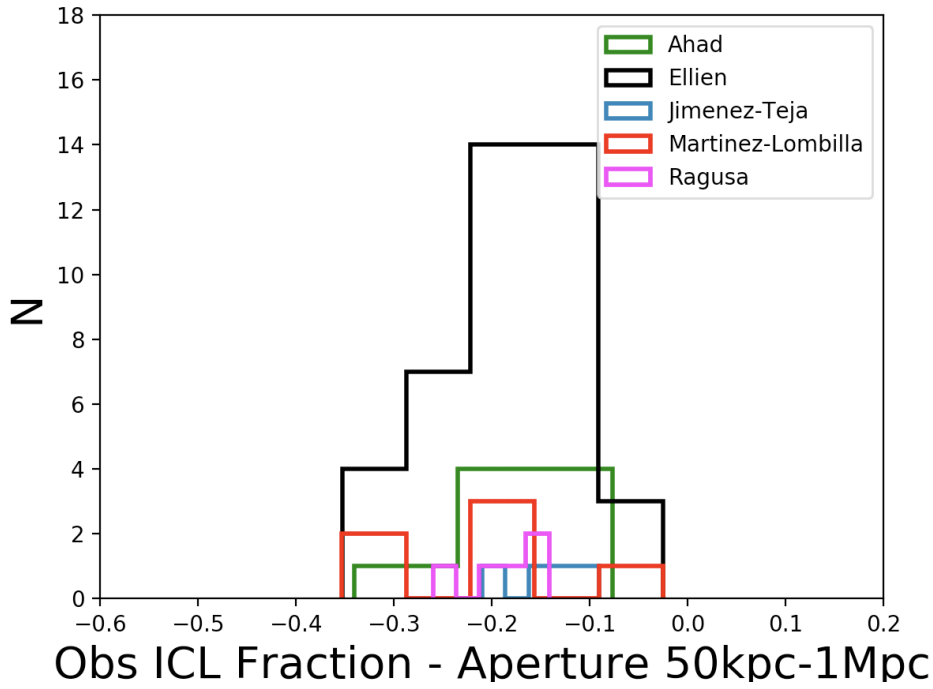
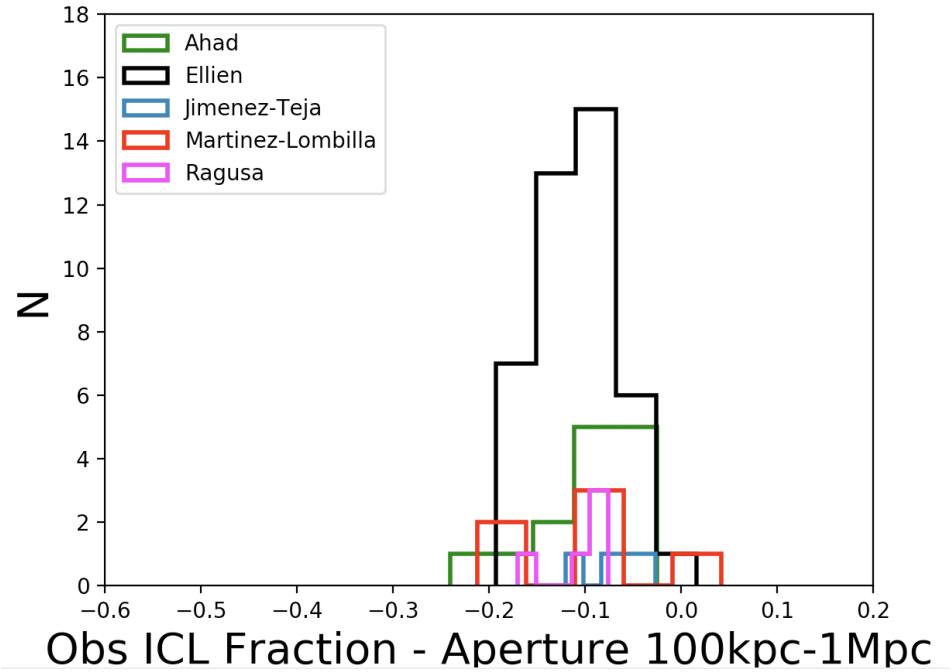


Figure 6 below: Histograms of difference Obs ICL Fraction (xy projection) - 4 different simulation measures







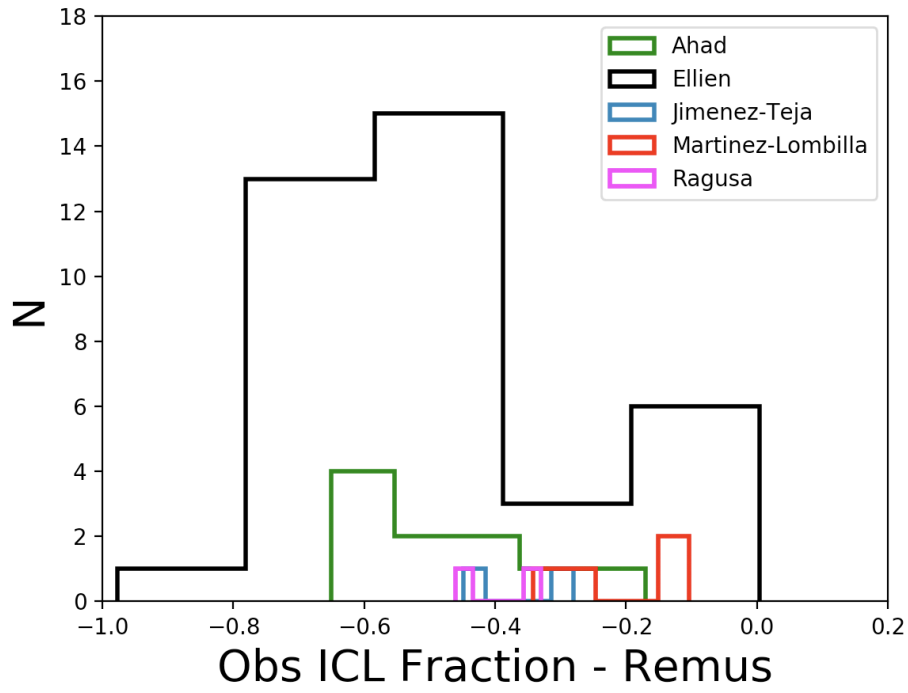
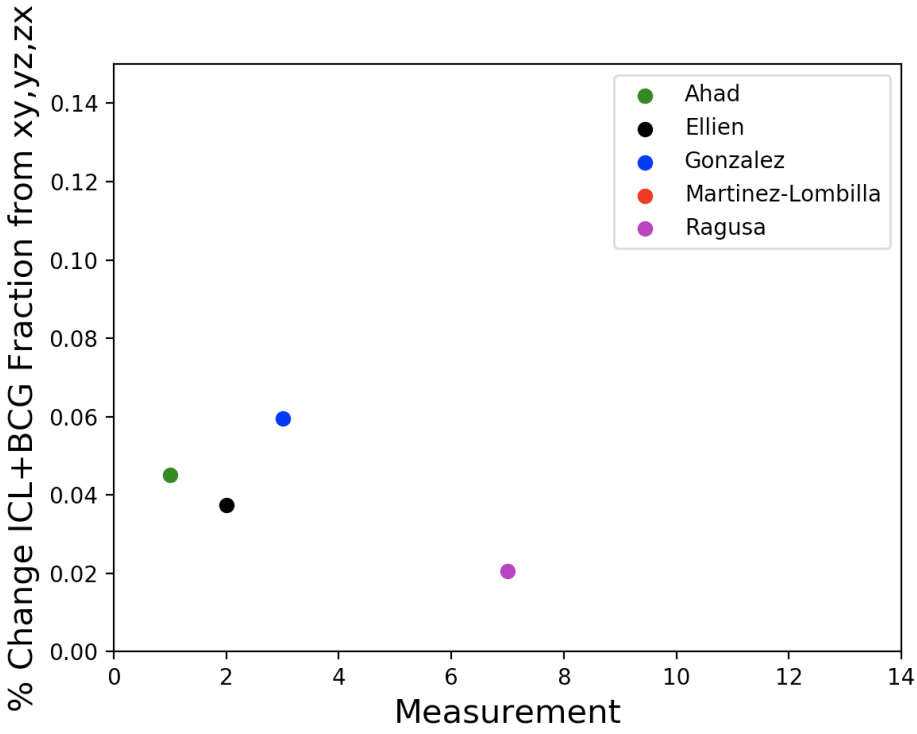
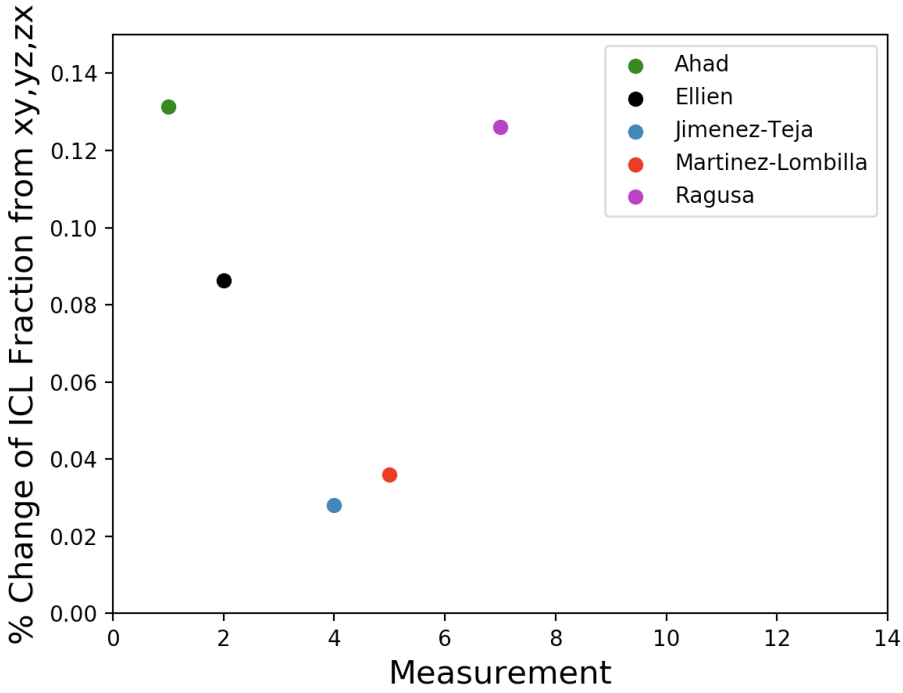


Figure 7 Below: % change (1=100%) **mean (standard deviation/mean)** of observers measurement depending on projection xy,yz,zx for ICL+BCG Fraction and ICL Fraction - add uncertainties [CODE UPDATED 22/8]


% Change ICL+BCG Fraction from xy,yz,zx
Measurement
Ahad
Ellien
Gonzalez
Martinez-Lombilla
Ragusa
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
2
4
6
8
10
12
14


% Change of ICL Fraction from xy,yz,zx
Measurement
Ahad
Ellien
Jimenez-Teja
Martinez-Lombilla
Ragusa
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
2
4
6
8
10
12
14

OVERLEAF LINK

In a moment of real over enthusiasm I have created an overleaf file. Right now it has author names (please email me if you have comments about the very initial author order), and some section headings… This link should give editing permission so please feel free to add your affiliations and text on your simulation / method. Email me or add a comment with any thoughts on section headings and I will fix them. When I have time over the next few weeks I will pull an introduction together.

https://www.overleaf.com/9678322939grkxnzkygpbv

2022/07/20 Meeting ICL Squad

July 20th, 9pm Australia, 7am US East Coast, 12pm UK, 1pm Europe
https://unsw.zoom.us/j/9215829921

Attendees: Sarah, Mireia, Cristina, Amael, Anthony, Lammim, Yannick, Annalisa, Nina, Garreth
Apologies: Rossella, Yoli, Rhea, Lucas

Agenda:

1. Figure discussion
2. What we still need:
   Observers please check whether you have used the mu_30.3 r-band cubes (i.e. how meaningful are these initial plots?)

   Garreth to make a test set of smaller cubes for observers to check the effect of those smaller cubes - can do by next week. 1 YY cubes from each of 4 simulations. So 4 cubes. 2*2*2Mpc.

   Can observers please make their measures on the smaller cubes before meeting in 3 weeks time (~ 8 Aug)? SB to send doodle.

   When decision re smaller cubes made, observers to make as full a set of measurements as possible please!

3. Any comments on overleaf sections?
   Write ONE BRIEF paragraph on the overleaf about the methods to measure ICL ? Observers and simulators.

Is it possible for observers to state the maximum circularized radius where dominated (>50%) by BCG and minimum where dominated by ICL (>50%)?

TO DO (by next meeting in ~3 weeks)

- **Garreth** to make & share 4 mini cubes [DONE 21/7/22]
- **Garreth** to add paragraph on how to luminositize the simulations to overleaf
- **SB** to send doodle re next meeting in ~3 weeks. [DONE 21/7/22 https://doodle.com/meeting/participate/id/bk540ZNe]
- **Observers** to make measurements on the new (smaller) cubes [DONE]
- **Observers**: Check and confirm surface brightness limit of mock images you are using (below Key Settings table). [DONE]
- **Simulators** to calculate luminosity fractions
- **Observers and simulators:** One brief paragraph on measurements in the Overleaf
- **SB** to update plots following today's discussion and outline introduction in Overleaf

2022/08/10 Meeting ICL Squad

August 10th, 7am US West Coast, 10am US East Coast, 3pm UK, 4pm Europe, 11pm Korea, and midnight in Australia https://unsw.zoom.us/j/9215829921

Attendees: Sarah, Garreth, Mireia, Yoli, Amael, Lammim, Rhea-Silvia, Lucas, Rossella,
Apologies: Cristina, Anthony, Yannick, Nina, Annalisa

Agenda:

- Go through Action Items from last meeting.
    - 2Mpc cube: Rossella, Cristina, Lammim, Mireia found results nearly identical with smaller cube. Any differences <1% in fractional change.
    - SB limits:
        - Cristina: 30.3
        - Rossella: 30.3
        - Mireia: 30.3
        - *Amael: 30.0 - *not limited to 1Mpc radius* (as of 20.07.2022) - is redoing
        - Lammim: 30.3
        - *Anthony: 31 - is redoing (as of 10.08.2022)
        - *Yoli: 30.0 - is redoing (as of 10.08.2022)

- Discussion re luminosity for mock images vs mass for simulations: If simulations changed the same way that mock images are created, then how . Aim not to tune M/L ratio to achieve the same fraction. Aim is for both sides to measure the same thing - e.g. maybe ICL mass fraction of 50% in simulation then potentially with M/L + projection effects the mock image luminosity measurement could be different%

- The change in fraction and/or M/L ratio could also relate to radius of the observational split between BCG-ICL? Contini explored radius ~15-70kpc with 60 more or less radius? Changes based on dynamical state of BCG.

Contini's paper: https://ui.adsabs.harvard.edu/abs/2022ApJ...928...99C/abstract
It would be interesting to compare at what radius those observers who do study the separation, find that separation to be at.

- Timeline from here: aiming to submit a paper summarising this work by the end of this year. This still seems do-able.

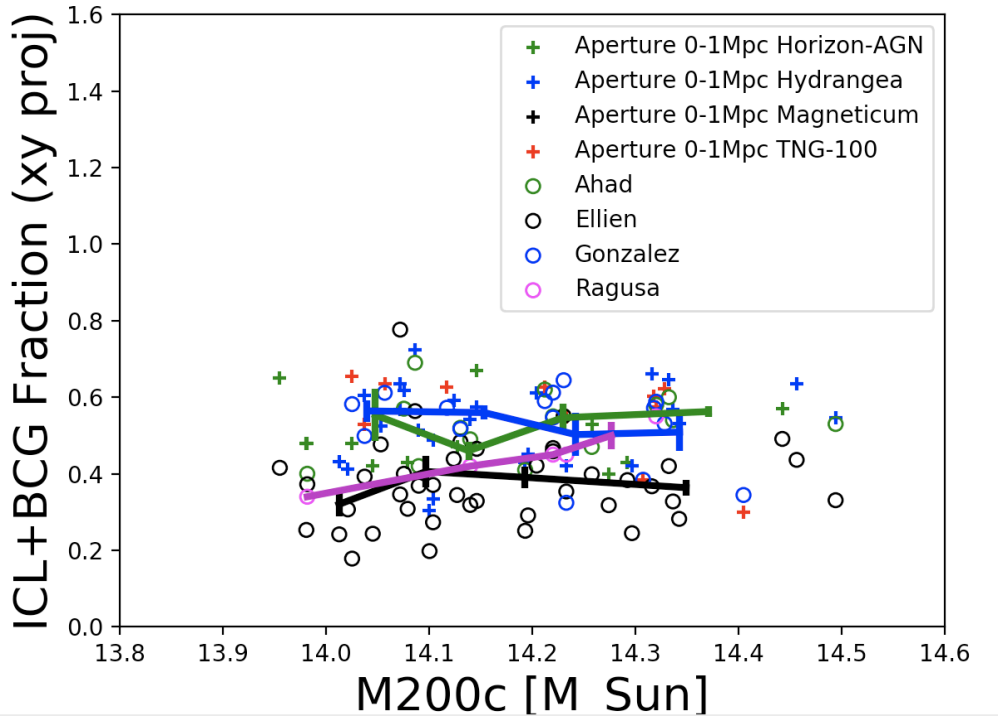
Next Meeting August 31st 9pm Australia, 7am US East Coast, 12pm UK, 1pm Europe
https://unsw.zoom.us/j/9215829921

TO DO LIST:

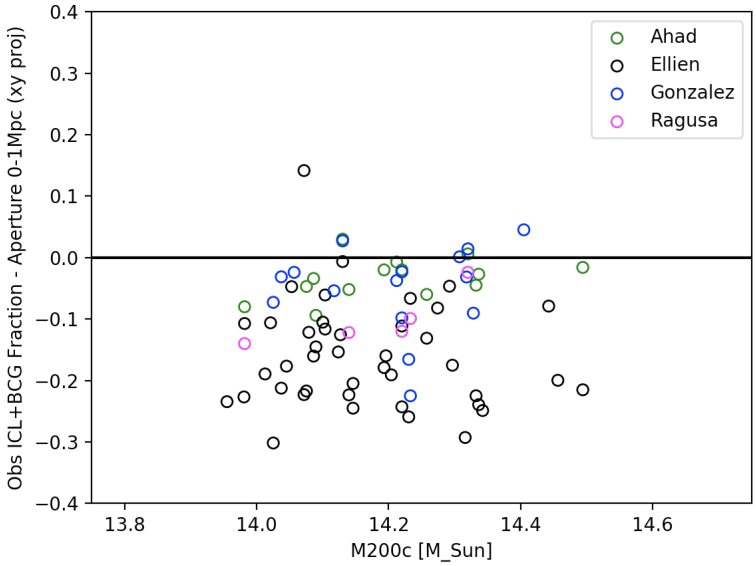
- **Garreth** to add paragraph on how to luminositize the simulations to overleaf (provide luminosities in the 3D cubes)
    - I have added a new set of files to the particle_data directory of the dropbox
    - There is a corresponding file to each .hdf5 file (.hdf5.lum) that gives the luminosity of each particle in solar luminosities - G
- **Simulators** to calculate luminosity fractions
- **Magneticum** to add more clusters to have similar sample sizes between the different simulations (Magneticum 4, TNG-100 11, Horizon-AGN 14, Hydrangea 27 clusters)
- **Amael, Anthony, Yoli** to update SB limits as needed
- **Observers** (those who separate between BCG&ICL) to add the radii at which the separation between BCG and ICL is made (~ where ICL light dominates over BCG light)
- **Observers and simulators:** One brief paragraph on measurements in the Overleaf
- **SB** to update plots following last meeting's discussion [DONE] and outline introduction in Overleaf [Kinda done]

2022/08/25 Updated Plots

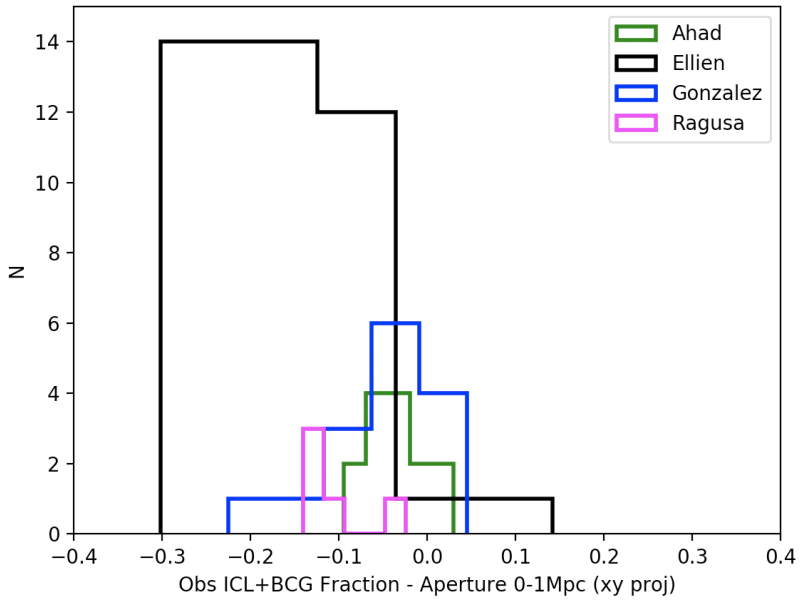
1. **Figure** below: Updated OBS ICL+BCG Fraction (xy projection) vs cluster mass with mean values per cluster mass bin. Here are measurements from 53 simulated clusters, across 4 simulations. (FIX COLOURS/POINTS!).



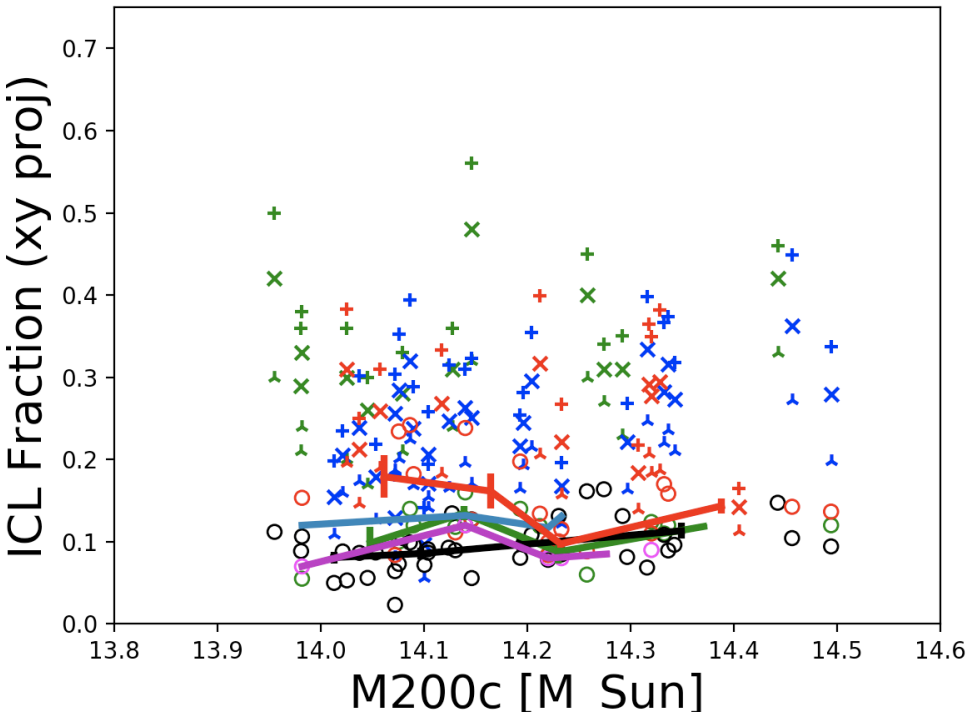
2. **Figure** below: Difference OBS ICL+BCG Fraction (xy projection) - Aperture 0-1Mpc as a function of cluster mass [Indicate different simulations]



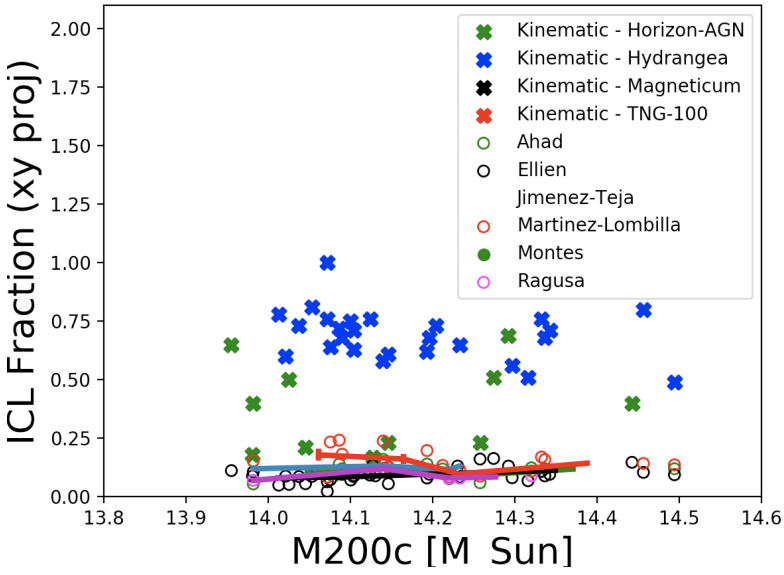
3. Figure below: OBS ICL+BCG Fraction(xy projection) - Aperture 0-1Mpc Histogram.



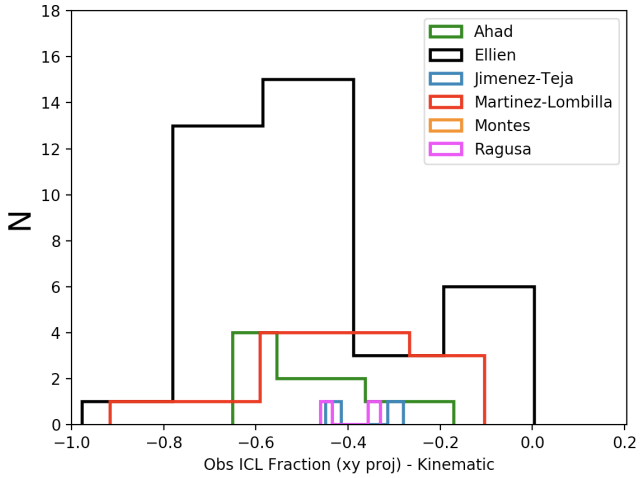
4. Figure below: OBS ICL Fraction (xy projection) vs cluster mass with aperture measures (crosses)

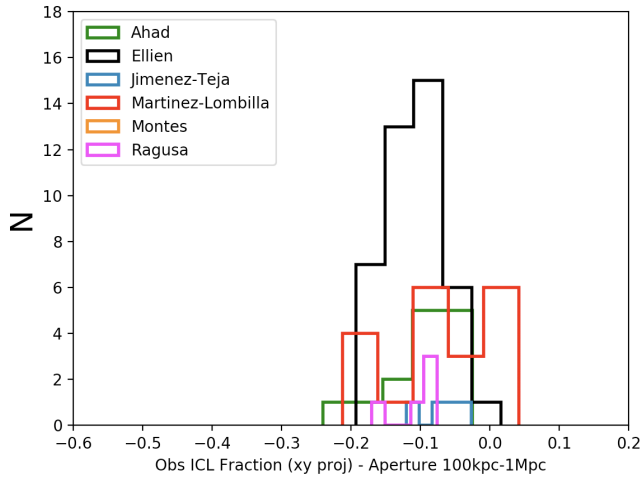


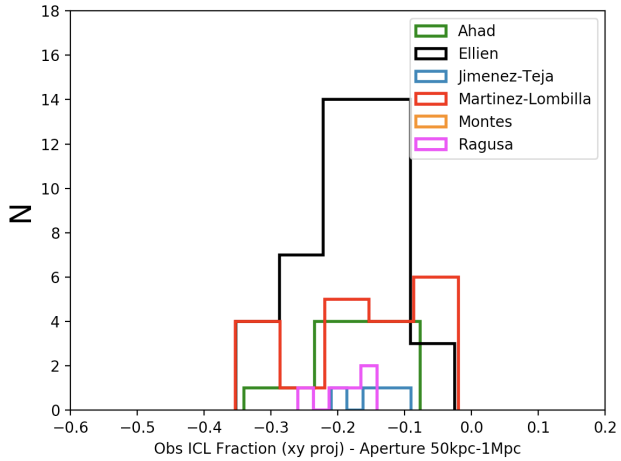
5. Figure below: OBS ICL Fraction (xy projection) vs cluster mass with kinematic measures.

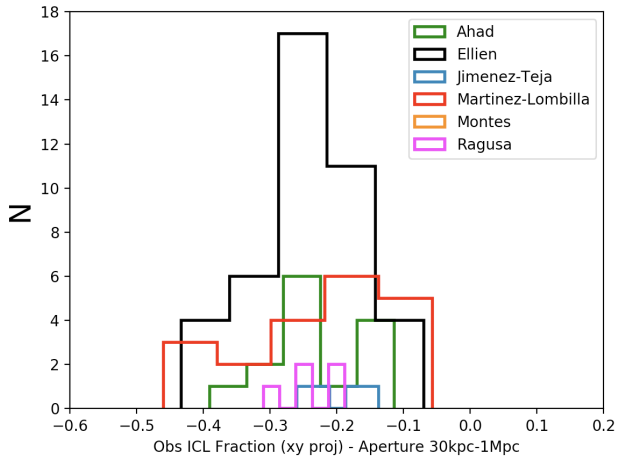


6. Figures below: Histograms of difference Obs ICL Fraction (xy projection) - 4 different simulation measures

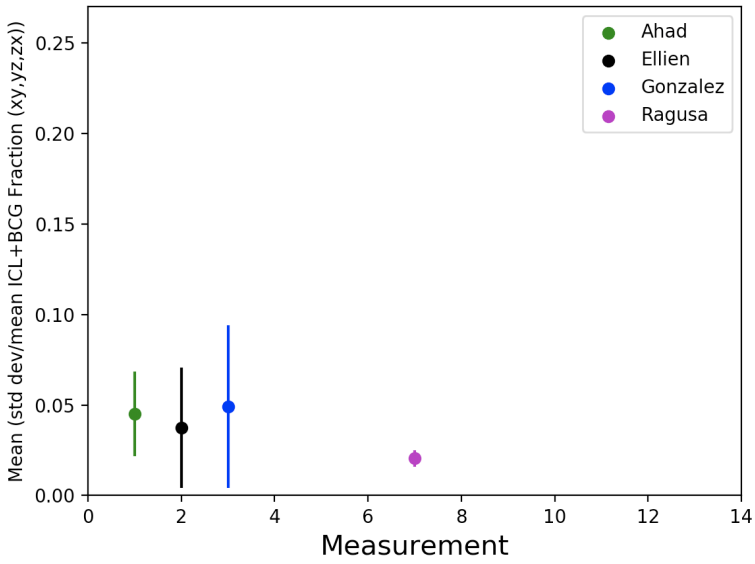




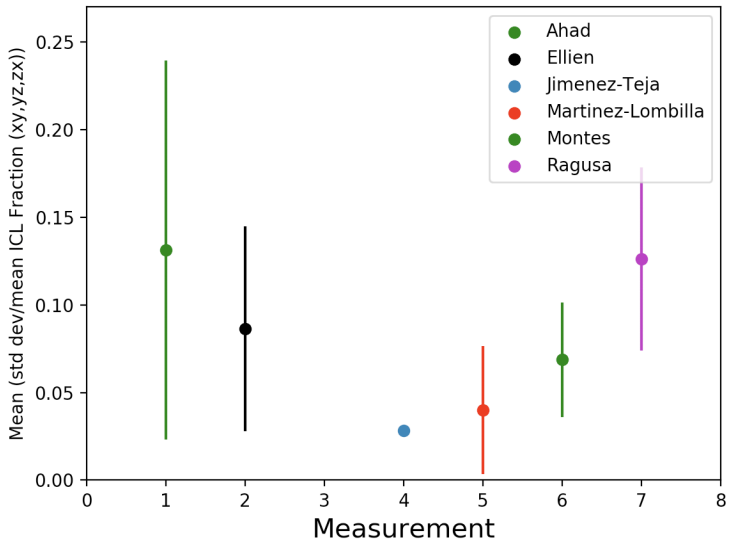




7 Figures Below: % change (1=100%) **mean (standard deviation/mean)** of observers measurement for xy,yz,zx projections for ICL+BCG Fraction and ICL Fraction. Error bars show standard deviation around this.



New idea: 3 projections -> range in ICL fraction
Plot here mean of range with std deviation as error bars for all clusters



2022/08/31 Meeting ICL Squad

August 31st, 9pm Australia, 7am US East Coast, 12pm UK, 1pm Europe
https://unsw.zoom.us/j/9215829921

Attendees: Sarah, Yannick, Mireia, Lammim, Anthony, Rhea-Silvia, Lucas
Apologies: Rossella, Garreth

Agenda:

- Go through Action Items from last meeting.
- Figures -> If we had different point types for the 4 different simulations, and a unique colour per observer as well as for the 5 simulation measures (with these 5 also bolder/larger points) - would that work to disentangle all the pieces of information? https://www.color-hex.com/ One plot to indicate how simulations sit/compare BUT maybe showing each simulation as a different point type makes the plots too busy. Similar methods similar colours!

STILL NEEDED:

Observers:
Amael - update SB limits
Anthony - update SB limits (magneticum and TNG done, horizon or hydrangea by the end of the week)
Cristina - add more systems & ICL+BCG (~20) - all Yes systems. asked re ICL+BCG tricky thing is the mask for some clusters, requires a lot of masking.
Lammim - add more systems (currently ~15)
Mireia - add more systems & ICL+BCG (~24) - trying to use GALFIT for ICL+BCG, would not fit well…
Rossella - add more systems (currently ~5, analysis of other cubes before the next meeting)
Yolanda - update SB limits (?)
ALL - radii (SB to add columns to spreadsheets - DONE)
Asked how tricky radius measures are: Mireia needs to work out more automatic way… (MM: will share with Cristina once I have it - thanks!)
Lammim also trying to figure out how to do this - has 1D profile, working out how to calculate/measure at which radius is >50% of light .

Simulators:
Annalisa - kinematic measures
Rhea and Lucas - kinematic measures. Other clusters - coming
ICL Fractions for luminositized cubes. Data available:
https://www.dropbox.com/scl/fo/bt2mjwa6f2nhxzyzk0onw/h?dl=0&rlkey=axnjtebivzj6wpslc0w1ujxtt

Plots (SB):
COLOURS (DONE 5/9)
Fig 1: Plot mean of 3 projections in plots (Std dev later) DONE THROUGHOUT 5/9
Fig 1: Just have 1 simulation point type (DONE 5/9)
Fig 1 - where is magneticum (BUG FIXED 5/9)

Fig 4. Sims agree on average so don't separate simulations (DONE 5/9)
Fig 4: Different sizes for the different apertures instead of different markers. (DONE 5/9)
Fig 4: Where is magneticum? (BUG FIXED 5/9)
Fig 5: Don't separate simulations (DONE 5/9)
Fig 6. Combine aperture histograms together (DONE 5/9)
Fig 7. Change to range… (DONE 5/9)

Extra plots TBD:
- Variance in individual cluster measurements
- Add plot to capture differences in simulations
- Analyse radii when have those measures

2022/09/05 Updated Plots

Fig 1: Observed ICL+BCG Fraction (mean over 3 projections) vs cluster mass with mean values per cluster mass bin. Here are measurements from 53 simulated clusters, across 4 simulations.

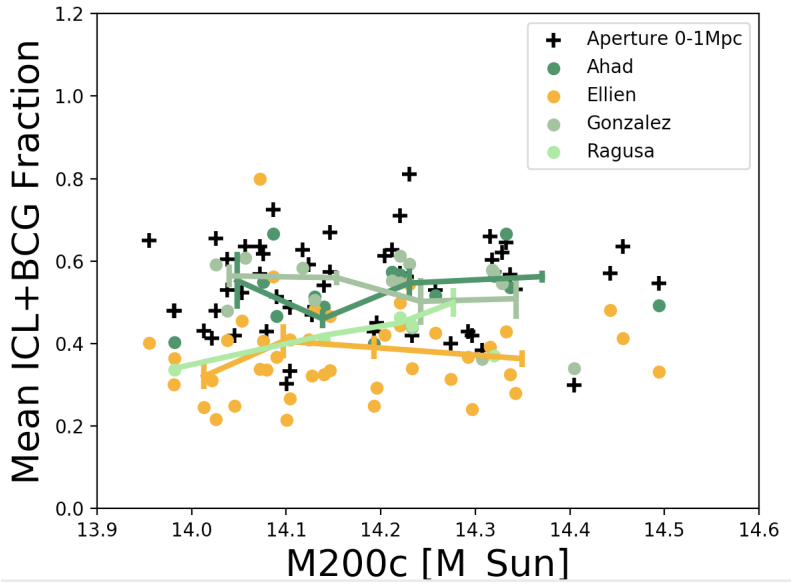


Fig 2: Difference observed ICL+BCG Fraction (mean over 3 projections) - Aperture 0-1Mpc as a function of cluster mass, across 4 simulations

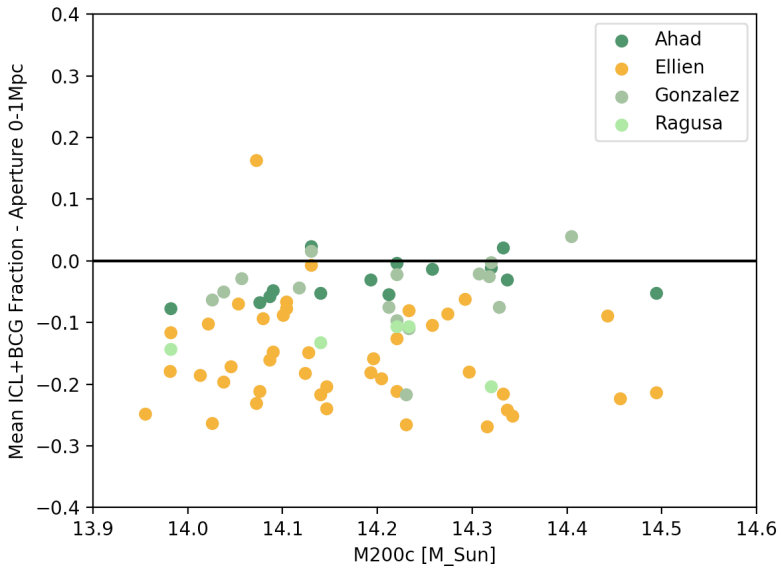


Fig 3: Observed ICL+BCG Fraction (mean over 3 projections) - Aperture 0-1Mpc Histogram, across 4 simulations

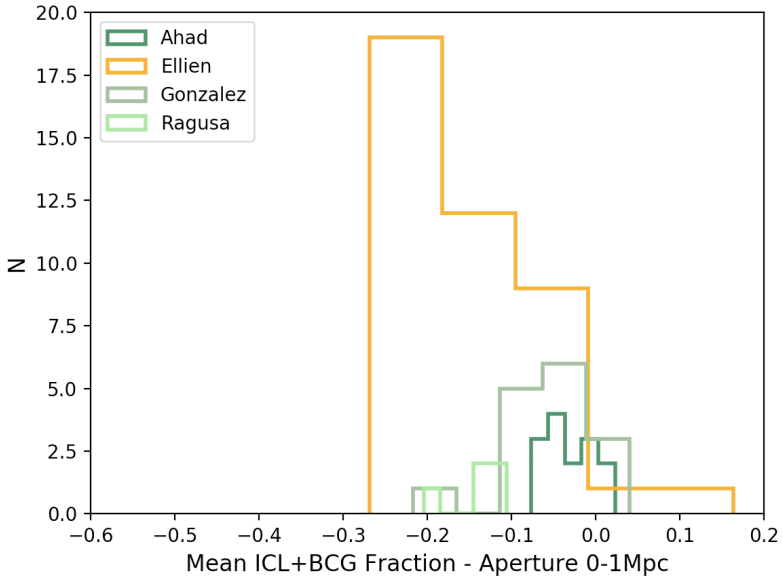


Fig 4: Observed ICL Fraction (mean over 3 projections) vs cluster mass with aperture measures [LABELLING - REDONE 14/10]

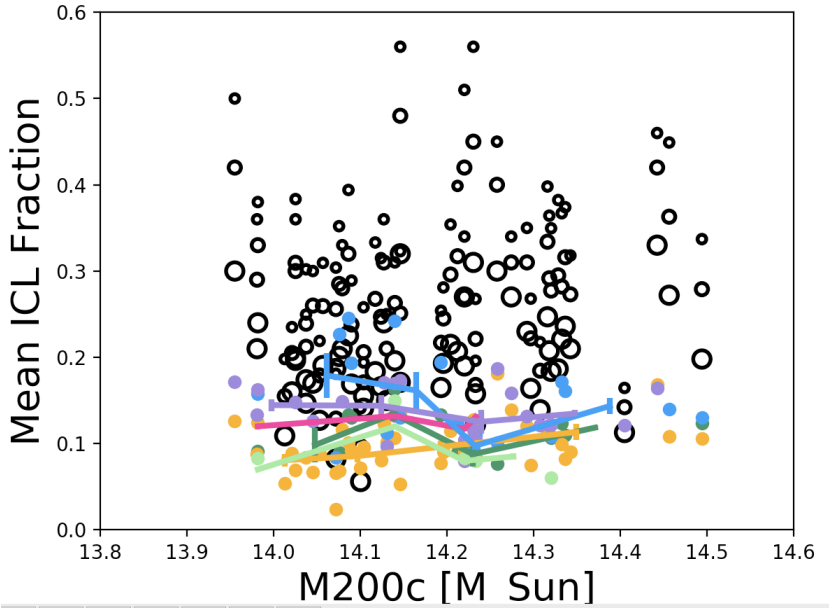


Fig 5: Observed ICL Fraction (mean over 3 projections) vs cluster mass with kinematic measures. [Check 1.0 kinematic fraction]

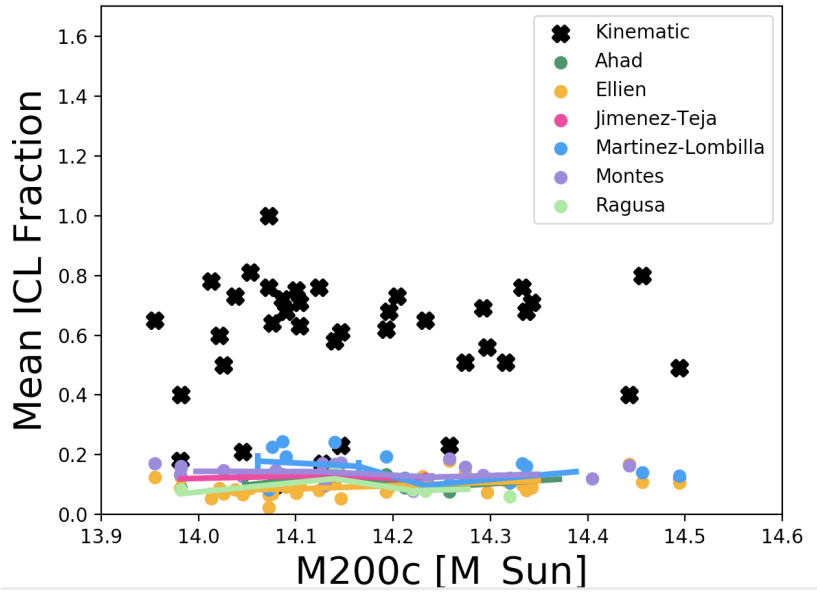


Fig 6: Histograms of difference between observed ICL Fraction (mean over 3 projections) for the 3 different aperture measures [LABEL APERTURES - DONE 14/10]

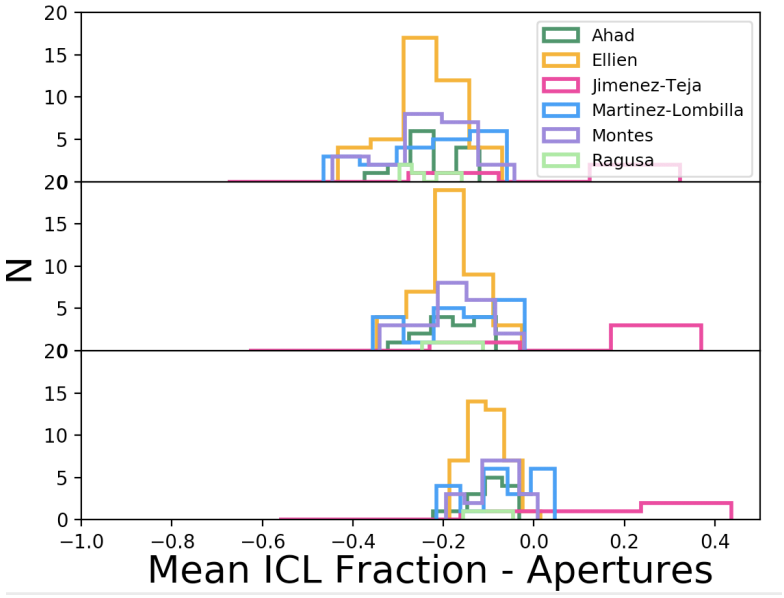


Fig 7: Histograms of difference between observed ICL Fraction (mean over 3 projections) for the kinematic measures

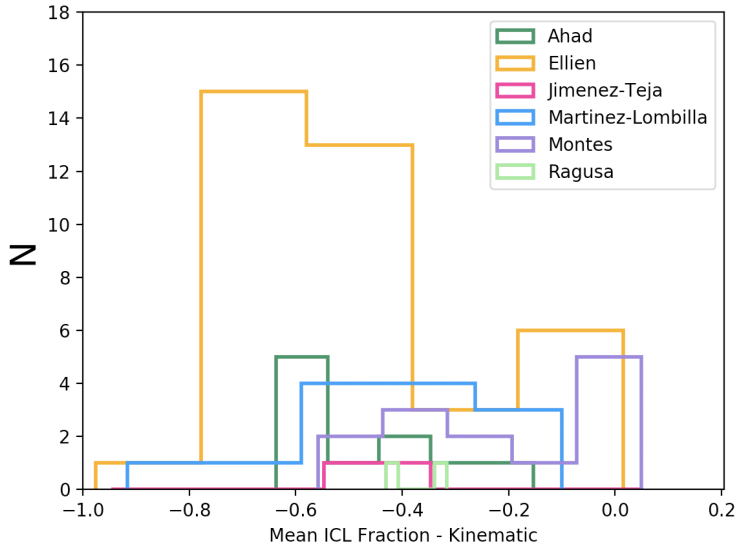


Fig 8: Mean of range of ICL fractions over 3 projections, error bars show standard deviation around that mean for all clusters for each measure

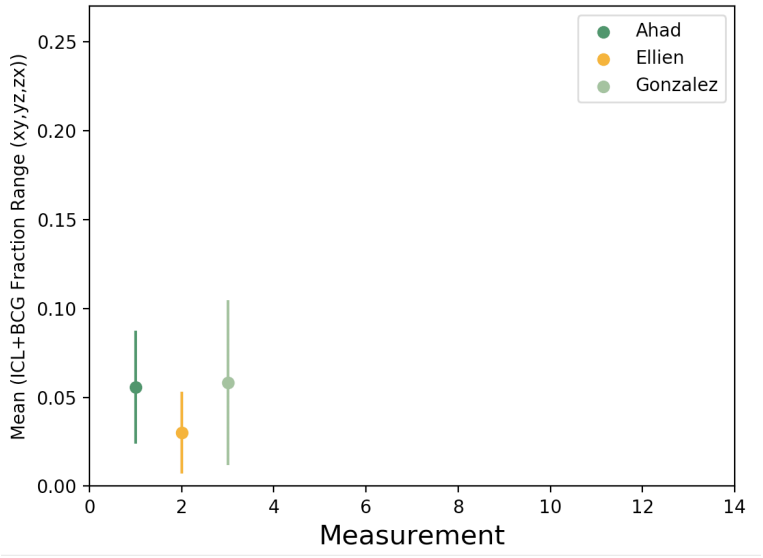
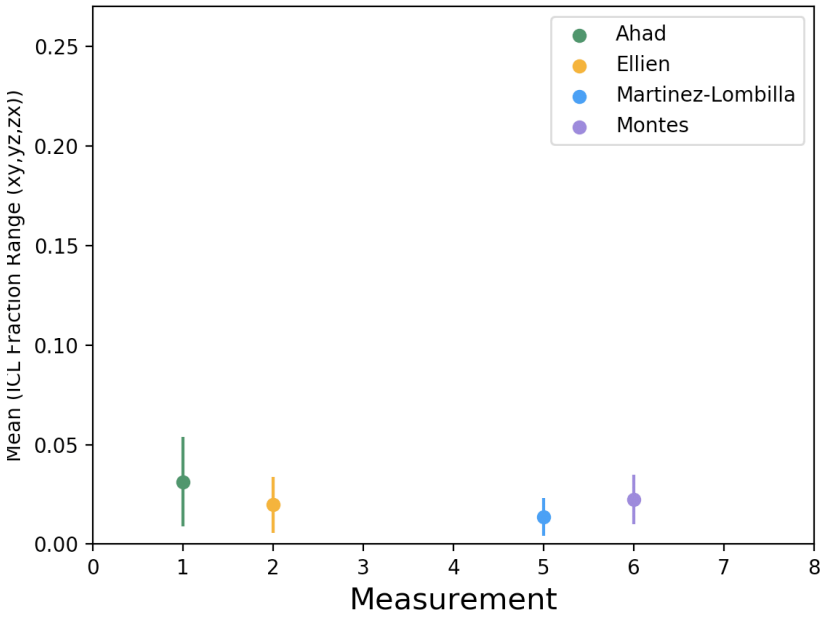


Fig 9: Mean of range of ICL+BCG fractions over 3 projections, error bars show standard deviation around that mean for all clusters for each measure



2022/09/21 Meeting ICL Squad

September 21st, 9pm Australia, 7am US East Coast, 12pm UK, 1pm Europe
https://unsw.zoom.us/j/9215829921

Attending: Sarah, Garreth, Rhea-Silvia, Lucas, Yoli, Cristina

Apologies: Rossella, Lammim, Mireia, Amael, Nina, Annalisa, Anthony

ACTION ITEMS:

Observers:
Amael - update SB limits [DONE, working out what to send through]. Radius measures? Add paragraph in overleaf on method.
Anthony - Add paragraph in overleaf on method.
Cristina - Add more systems, ICL+BCG & radius measures [Will do more soon]
Lammim - Add more systems [DONE, will add to spreadsheet by next meeting]. Radius measures? Add your method to the existing overleaf paragraph.
Mireia - Add more systems, ICL+BCG if possible and radius measures
Rossella - Add more systems & radius measures [Will do more soon]
Yolanda - Update SB limits to 30.3. Add ICL and ICL+BCG Fractions and radius measures Add paragraph in overleaf on method.

OVERLEAF: https://www.overleaf.com/project/62ce6ed7f4e037c574f0841c

Simulators:
Rhea and Lucas - Kinematic measures. [SB to add new cluster names to spreadsheet]
ICL and ICL+BCG Fraction for luminositized cubes.
Annalisa - Add kinematic measures. Overleaf section on Illustris & aperture measures. ICL and ICL+BCG Fraction for luminositized cubes.
Yannick - Overleaf section on Hydrangea & aperture measures. ICL and ICL+BCG Fraction for luminositized cubes.
Garreth - Add description of mock images & Horizon to overleaf and a pretty figure of the mock images from the 4 simulations

Luminositized cubes:
https://www.dropbox.com/scl/fo/bt2mjwa6f2nhxzyzk0onw/h?dl=0&rlkey=axnjtebivzj6wpslc0w1ujxtt

Plots: See above
New plot on overleaf from Rhea-Silvia&Lucas - **would like feedback from simulators** https://www.overleaf.com/project/62ce6ed7f4e037c574f0841c [SB & Garreth like it]

SB - Tweaks to current plots:
Fig 4: 3 in a row, 1 aperture on each plot => DONE 14/10
Fig 5: in legend command ncol changes number columns. or remove legend and rely on previous figures in overleaf => DONE 14/10
Make 6b same scale as 6a => DONE 14/10
Change fig 7 x-axes to names => WORKING ON…

SB - Extra plots needed:

- Variance in individual cluster measurements [WORKING ON 14/10]
- Add plot to capture differences in simulations -> mass on x-axis (no trend on x-axis). Aperture measures vs mass. Kinematics vs mass. With colours per simulations. Show the good agreement. [DONE 14/10]

- Analyse radii when we have those measures (TBD]
- Simulated luminosity ICL and ICL+BCG Fractions when we have those measures [TBD]

SB will doodle for next meeting [DONE]

2022/10/19 Meeting ICL Squad

October 19th, 10pm Australia, 8pm Korea, 7am US East Coast, 12pm UK, 1pm Europe ?
https://unsw.zoom.us/j/9215829921

Attending: Sarah, Lammim, Mireia, Cristina, Lucas, Rhea, Rossella, Anthony, Amael, Annalisa, Yoli, Yannick
Apologies: Garreth

Agenda:

1. Where are we at with observed measures?
    a. Amael - TNG clusters. (If zero - then struggled to make measure) - STILL MISSING
    b. Anthony - All there bar new magneticum systems - WILL DO
    c. Cristina - Has checked and added more measures. Need to update those measures. Masking underway. (Question re what to do about tidal feature whether to include in ICL? Yes to include in ICL) - ADD FEW MORE MEASURES, STILL MASKING FOR ICL+BCG MEASURE. CALCULATING RADIUS FOR SB26MAGARCSEC^2 AND FOR BCG+ICL SEPARATION
    d. Lammim - Checked method. Numbers changed a little. Very difficult to get measures for some clusters. (What causes it not to work - lots of curves in radial profile). **USeful to know which systems fail and include in plots as limits… So indicate these in spreadsheet as dashes. ADDING MORE SYSTEMS. AND - WHERE FRACTIONS FAIL. 1D PROFILE SEPARATION, RADIUS IN KPC WHERE ICL>50%TOTAL.
    e. Mireia - need to finish TNG & Hydrangea clusters with SB method. And figure out problem with 2D decomposition, tried with one from Horizon-AGN. GALFIT wouldn't do a good job. **Two methods - will plot more than 1 method as Surname 1 and Surname 2. Will be good to add surnames into methods in overleaf to connect to plots.
    f. Rossella - Added few clusters. Working on adding more soon. Just need time

g. Yoli - Running to have higher number of measures ready. Not following any particular order. 5 more clusters measured that will add to spreadsheet. Will continue running code. Using right SB limit. Will add paragraph to overleaf. SB TO LOOK AT OVERLEAF ACCESS. ADDING MORE MEASURES. WORKING OUT EQUIVALENT RADIUS FOR REGION.

2. Where are we at with simulated measures?
    a. Rhea & Lucas - more magneticum clusters to be added. Lucas to email SB with names [DONE] and SB to add to spreadsheet for measurements [DONE!]. Have aperture measures to add to spreadsheet already. Mock cubes? prepared by Garreth and also available for observers [SB checking location]. Rhea running kinematics will be able to add next week. NEW CLUSTERS. APERTURE METHOD and VELOCITIES METHOD ALL THERE! Not clear on what needed for luminosities. Make aperture measurements on luminosity 3d cubes to compare. If there are significant differences from mass cubes, then consider checking kinematic measures too.
    b. Annalisa - kinematic measures still on to-do list. TO BE DONE. ADDED SIm TABLE. ENSURE SIMULATION DESCRIPTIONS BRIEF ~1page.
    c. Yannick - trying to look at luminositized cubes but only 2D ? Will follow up with Garreth. One Hydrangea cluster 16000000294 returns kinematic measure of 1.0 . Starburst in centre throwing off measurements. Kinematic measures quite different from Horizon to Hydrangea. Did use the same code for measures. Garreth and Yannick to check their kinematic measures… HAS DATA NOW. FOUND MORE COMPLICATED THAN JUST CHANGING INPUT DATA. ADD LUMINOSITY DATA AS NEW TABS/SHEETS IN WORKBOOK. ADDED SHORT PARAGRAPH TO OVERLEAF

    [ALL: email SB when major updates to data spreadsheets so I can update plots]

    [ALL: Make sure paragraphs on methods/simulations added to overleaf]

3. Plots as they stand right now [in overleaf https://www.overleaf.com/project/62ce6ed7f4e037c574f0841c]

PLOT EDITS (SB):
Fig 3: plot black crosses last [DONE 22/11]
Fix Fig 4 [DONE 22/11]
Spread Fig 5 across 2 columns [DONE 22/11]. Keep lines [REMOVED 22/11…]
    Opaque points?
Flip Fig 9/10 axes. [DONE 22/11]
Change Fig 9/10 axes to names [DONE 22/11 **- BUT COLOURS]**
Variance in individual cluster measurements [DONE 22/11]
Avoid a/b/c/ just label. [DONE 22/11]

Move Fig 11 to beginning. [MOVED 22/11]
Add 2nd measures to plots (Amael - DONE 23/11; **Cristina, Mireia - need data)**
Plots showing how dynamical state of cluster affects measures **(in progress 23/11)**
Classify extra clusters [DONE 24/11]
Write Results section [DONE 24/11]
Adjust overleaf figs into groups [DONE 24/11]
Tidy Intro section [DONE 24/11]
Plot mass in BCG from sims [DONE 5/12]
Update measures used in plots [DONE 5/12]
Plot Radii [DONE 5/12]
Plot SIMULATED LUMINOSITY MEASURES (Horizon-AGN, Hydrangea - DONE 5/12; **Magneticum, TNG - need data)**

Still to do:
Plot showing obs measures grouped in wavelet vs SB vs sersic… ??
I haven't captured the 'not measured' points (-) yet…
Writing:
Sims Data section: Needs Illustris-TNG / descriptions of aperture / kinematic measures/ cluster selection
Discussion section [SB]

4. Remaining questions to try and understand differences between observers and simulators:
    a. Radius observers find ICL to be distinguish from (Regarding units - for kpc, what is z of simulations? And where observed from? Might not be safe to assume z~0 to convert to kpc? Use 5x5x5Mpc Cube size to give kpc/pixel ratio? On 22/03/09 in point 2-ii) Pixel size: 1kpc per " and 5XMpc cube - from the google doc . Rossella: 0.97kpc/")

    And 0.2"/pix so 0.194kpc/pix

    B. Do luminositized cubes make a difference to the fraction? These are available at https://www.dropbox.com/scl/fo/bt2mjwa6f2nhxzyzk0onw/h/particle_data?dl=0&subfolder_nav_tracking=1

5. Deadline? Still aiming for the end of this year!

Big picture: Everyone calling ICL / BCG different. This is amount they are different. One that is most similar is 100kpc-1Mpc. Good to check that observers separated radius is ~100kpc.

Next meeting in 3 weeks, SB will doodle for best time as will be after European clocks change [DONE].

2022/11/07 Meeting ICL Squad

November 7th, 10pm Australia, 8pm Korea, 7am US East Coast, 11am UK, 12pm Europe
https://unsw.zoom.us/j/9215829921

Attending: Sarah, Mireia, Cristina, Lammim, Annalisa, Yannick, Garreth, Yoli, Anthony, Rhea-Silvia
Apologies: Rossella

Agenda:

1. Where are we at with observed measures? (See the agenda from the past meeting to see the updates)
2. Where are we at with simulated measures? (See the agenda from the past meeting to see the updates)
3. Plot update….
4. Plan…

OVERLEAF:

TABLE FOR SIMULATION PHYSICS
TABLE SUMMARISING OBSERVATIONAL METHODS incl publications

For observers:
Guidelines for what to put in the measurements in the Google sheet:
— (dash): for tried but fail, blank: for not tried yet to do the measurement

2022/12/06 Meeting ICL Squad

Tuesday December 6th, 11pm Australia, 9pm Korea, 7am US East Coast, 12pm UK, 1pm Europe https://unsw.zoom.us/j/9215829921

Attendees: Yannick, Rossella, Lammim, Lucas, Amael
Apologies: Annalisa, Nina, Mireia, Rhea

Agenda:

1. **Discussing plots in overleaf:**

https://www.overleaf.com/project/62ce6ed7f4e037c574f0841c

-> Fig 3 upper panel: what masses are everyone using for the BCG? Magneticum & Hydrangea using total stellar mass from central component from subfind. What are Horizon-AGN (looks similar) using? **For Horizon, the total stellar mass from AdaptaHOP on the central component (which could differ a bit from Subfind but likely not much, as discussed in the paper) -GM**

Need to know what TNG BCG mass is (as looks offset - is this the mass within 2x ½ light radius? Can we get total stellar mass?) => AP 22.02.2023: Until now it was Mstars<30kpc. Numbers for any other aperture or choices are available (files to Sarah sent).

-> Fig 3 lower panel: discussion whether offset in Magneticum clusters due to higher/lower resolution. Lucas made a plot to show it's a result of their selection as low substructure rather than resolution.

-> Fig 4: Why are Horizon-AGN's kinematic measures lower? - the index convention needs to be checked as was changed for Hydrangea. NEED values for TNG **I think my fractions may be inverted (which I noted in the spreadsheet, I think), I will make sure, but it looks like they would match the other simulations much better if so -GM [**SB Changed in plots 18/1]

-> Fig 5 upper: SB considering removing lines as plot is BUSY! (DONE 16/1/23) Discussed that this particular measure - only difference is in 1. Picking up ICL light and 2. Satellite subtraction. Added Cristina ICL+BCG fractions 27/1/23. Mireia adding ICL+BCG fractions?.

-> Fig 5 lower: SB will add to overleaf that N so different due to observed sample sizes DONE 16/1/23, decided not to reduce cluster sample by ½ to maximise observers measures. The offset magneticum clusters haven't been measured by observers yet in this version - so not seen so offset in histogram. Lammim measuring those now and will update catalogue [DONE. SB UPDATED 18/1]. Rossella adding more clusters.

-> Fig 6 & 10: (SB to CHECK calculation! DONE 16/1/23) is larger scatter for more 2D than 1D measures / masking techniques? Fig 6 > Fig 10 due to larger measured fractions as these are absolute values. Scale by measured fraction? [DONE. SB UPDATED 18/1]. COLOURS [DONE 25/1].

-> Fig 8: Amael's size separation value is at 60kpc. Interesting that it is still offset from 50 or 500kpc simulated aperture measures. And SB - surface brightness measure offset from similar measures by Cristina and Mireia. Amael considering updating values.

-> Fig 9: ICL Frac = 1.0 is enormous starburst system in Hydrangea. SB will grey out.

-> Fig 11: Hydrangea scattering differently to Horizon-AGN. Likely different stellar populations/M/L ratios? But it is still 1:1 so still close relationship between mass and luminosity measures. From Hydrangea and Horizon-AGN like this could cause ~5% scatter compared to observers measures but no more. NEED luminosity aperture measures for Magneticum and TNG. Data available: https://www.dropbox.com/scl/fo/bt2mjwa6f2nhxzyzk0onw/h?dl=0&rlkey=axnjtebivzj6wpslc0w1ujxtt . The luminosities are in e.g. particle_data/Magneticum/00031_0000726.hdf5.lum

-> Fig 12: Observers radii. These are a lot larger than simulated apertures. But also a lot larger than ICL is normally measured out to for observational data! Hmm… (We could explore the simulators using observers radii to see if it 'fixes' fractions. But this alone is interesting.)

-> Fig 13: ICL_Frac_means.pdf "The mean ICL (upper panel) and BCG+ICL (lower panel) fractions across the various observational methods. One panel indicates the dynamical state of the cluster" SB to add error bars to show scatter [DONE 18/1] Add histograms for relaxed vs unrelaxed [DONE 18/1]. Check relaxed vs unrelaxed classification.

-> Extra:

1. Showing obs measures grouped in wavelet vs SB vs 1D vs 2D??
2. Capture the 'unable to be measured' points (-) - !Will add to TABLE!

-> OVERLEAF: Sims Data section: Needs: intro to TNG (Annalisa) / Description of kinematic measures (Rhea-Silvia) / Selection of clusters from ALL simulators)

3. **How bring together?**

- We can provide error bars on observational measures and any offsets between different measures as well as simulated measures
- Anything else?

Next Meeting -> SB on leave until at least 2 January. I will focus on this for a week after I return so will get in contact after I've done that regarding arranging our next meeting.

2023/02/22 Meeting ICL Squad

Wednesday February 22nd, 10pm Australia, 8pm Korea, 6am US East Coast, 11am UK, 12pm Europe
https://unsw.zoom.us/j/9215829921

Attendees: Sarah, Lammim, Amael, Rhea, Cristina, Mireia,Annalisa, Yannick, Lucas, Yoli
Apologies: Nina, Rossella, Anthony

Agenda:

What are we missing?

- Magneticum bits: table completed / text to be added / luminosity cube measures for Magneticum / plot which shows that Magneticum clusters are super relaxed!
- TNG Bits: How is the TNG BCG mass is measured as in Fig 3 it looks offset from the other simulations. Is it the mass within 2x ½ light radius? Might is be possible to get the total stellar mass?)
    - BCG mass is within 30kpc in text file. Magneticum is everything not identified by subfind to be in substructure. Only mask satellite galaxies. Energy binding

criterion. So BCG+ICL. SB to change ‘BCG’ mass to Col F: 0kpc-1Mpc aperture BCG+ICL (no Sats) Mass [M_Sun] for ALL simulations.[DONE 17/4]

- Kinematic measures for the TNG clusters? Aperture measures for the luminosity cubes of the TNG clusters? SB to follow up with Garreth/Yannick/Annalisa [DONE, ADDED 16/4]
- Brief intro to TNG (DONE) and some comment on how the TNG clusters were selected in the overleaf (Will tidy)

Check names - Magneticum 31, different name for box 2b.
Cluster selection: Hydrangea all? Horizon-AGN all? Magneticum - most relaxed to downselect from ~4000. TNG - 10^14-10^14.5 range. [DONE 17/4]

Be clearer about ‘Fraction: ‘ throughout [DONE 17/4]
‘Sim Aper’ clearer that simulated measures [DONE 17/4]

Reasons why less ICL in observations than simulations: Measure of how well each excising satellites. Observations - Cylinder excised - everything in front and behind is subtracted compared to simulations which subtract sphere. ~Factor of 2? Also LSST SB limit applied to create mock images - is light lost there?

Reason why MORE ICL in some observations than in simulations? Tends to be wavelet measures: DAWIS (not masked)/CICLE. Amael is re-doing his. [Plots updated 13/4]

Across haloes we’re studying, projections responsible for projection effects as large as 0.3dex.

>PLOT showing same cluster, same projection measures.

ICL. Differences boil down to separating ICL from BCG. Discussion - does this mean that ICL boundary is at 100kpc? Compare radii in Discussion? Interpretation of how well apertures work - physical reason for choosing apertures. What is median? And distribution. 100ish? OK approximation. Scatter in radii is large, driven by something - what is the something? Not in this paper, next one. Mireia: No no, it is not physical, but it is nice to see that is quite consistent with the 100kpc aperture from the simulators.

Ran out of meeting time. Will continue, focussing on figures and meaning and discussion sections in 2 weeks. Thanks everyone!

2023/03/08 Meeting ICL Squad

Wednesday March 8th, 10pm Australia, 8pm Korea, 6am US East Coast, 11am UK, 12pm Europe
https://unsw.zoom.us/j/9215829921

Attendees: Sarah. Garreth. Anthony. Amael. (Yannick later). Annalisa. Cristina. Lammim. Mireia. Rhea. Yoli
Apologies: Nina. Rossella. Lucas.

- Updated measures from Rossella and Amael in last fortnight, but figures still to be updated (SB) [DONE 13/4]

- Rhea: Shared figure showing Magneticum BCG / ICL fraction with selected clusters identified and relaxedness of clusters indicated. Yoli - observationally finds ICL fraction higher for non-relaxed clusters. (Right figure, with clusters marked, colour. Rhea to update and add to overleaf)

Continue going through paper, focussing on figures and meaning and discussion sections in 2 weeks:

Figure 8: ICL kinematic separation. These observational methods are measuring something quite different. WHY / WHAT included a question for another time? Implications should be highlighted - kinematic measures suggested . Rhea's paper compares kinematic ICL observations with simulated measures and finds those are consistent.

Separate section with Figs 5/9 in same figure - section "Projection Effects" . Randomness of projection produces larger uncertainties when trying to isolate ICL compared to isolating BCG+ICL. [DONE 17/4]

Figure 10: Just based on particle properties. Simulation metallicities and ages are different. But differences are less than 0.1dex observed in Fig4, so may contribute but is not whole story of difference between observations and simulations. 'CONCL: Given effects of projections and different ways of measuring things. Cannot constrain models with single objects.' (Replot as ratio vs 1 or the other. [DONE 17/4])

Figure 11: AP - do we see radius/mass dependence? Mireia/SB not trusting that over small mass range with few measures at highest mass. SB to plot mean/mass/measure. [DONE 17/4]

Limit sample to 10^14-14.5 mass range as initially intended… [DONE 17/4]

Figure 12: Error bars are "". Colour separation. More robust relaxed definition we could apply? Sims -> / Obs -> ? M1-M5 ? **Rhea definition would work well - will do. F8 traces assembly history (Kimmig+ paper)**. Yoli pointing out no observed difference in ICL fraction with cluster relaxedness in r-band at z~0. Relaxed/unrelaxed - comparing clusters at different stages of evolution. What does plot add? For obs + sims, BCG+ICL trend. ICL no trend. Important because makes statement about selection - does not drive results. Put histogram on right-hand axis. Then combine 2 plots. Wording emphasise what actually looking at here, not trying to say would observe difference or not.

Yoli - If we want to do separation, separate samples need to be well-defined - maybe with simple definition is not showing something physical?

Examine largest obs - sim offset visually examine to investigate what is driving difference? Hand wavy.

NEXT STEPS: SB to update / edit plots and paper text. March is BUSY so this will take a while. Once ready I will share with everyone for your comments. Thanks once again!

2023/05/16 Meeting ICL Squad

Wednesday May 16th, 9pm Australia, 7pm Korea, 12pm UK, 1pm Europe
https://unsw.zoom.us/j/9215829921

Attendees: Sarah. Anthony, Garreth, Mireia, Lammim, Lucas, Yannick, Rhea, Nina, (Amael)
Apologies: Annalisa, Rossella

Paper discussion:

- Move Table 1 to appendix. [DONE 16/5/23]
- Have edited to M_tot (or L_tot) throughout (M*,tot) [DONE 16/5/23]
- Fig 1 - invert colourmap? Black -> White please Garreth, thank you!
- Connect to new relaxed systems section in Results. [DONE 16/5/23]
- Table 2 & 3,
    - subheadings for method [DONE 16/5/23],
    - add mean of those. [DONE 16/5/23]
    - “Mean Range”->”Projection Scatter” [DONE 16/5/23]
- Interesting that similar trend for each of the methods. Inherent difference from modelling clusters in different projections is significantly different from measurement scatter. [DONE-ISH 16/5/23]
- Capture mean+rms (observed-simulated) for each of 4 simulations DONE 16/5/23
- Fig 3,4&5 points… Add some transparency. HMM… DONEISH 16/5/23
    - Fig 4 3xcolumn legend. Decrease y axis. DONE 16/5/23
    - ?Double rows: 1 row points, transparencies, 2nd row trend lines?
- Mireia+Cristina SB methods similar and similar scatter suggesting observer involvement not significant impact. [DONE 16/5/23]
- Add discussion on scatter to kinematic comparison [DONE 16/5/23]
- Discussion: kinematic + image measuring two quite different things. [DONE before]
- Luminosity measures for Fig 9 - Underway for magneticum. ‘F_M/F_L’ [DONE 16/5/23] In essence, before we consider differences in observers method. Need to consider projection - as huge difference. And consider distribution of metals model implemented in making luminosity measures as makes important difference. [DONE 16/5/23] Keep to

comparing with simulated mass measures throughout as this is the usual comparison made
- Move projection section to discussion [DONE 16/5/23]
- New Fig 8 - keep? NOPE [DONE 16/5/23]
- A Figure & numbers to show scatter PER cluster with different measures… DONEISH 16/5/23
    - PLOT AS MIN->MAX not rms. [DONE 23/5/23]
    - Add to text
- S5.3: Scalability 🙂Automated masking IS possible… Lammim's paper, more than 500 groups, next paper 2000+ to come. Built for statistical analysis. "Up to this point, algorithms haven't needed to be made to be scalable, effort needed to make them scalable". [DONE 16/5/23]
- Set these data up as standard reference in location? Large files - where to put? Subset of reference clusters? Magneticum fine.

SB - I need to share with wider Rubin LSB WG/Challenge#3 group (ie not just this ICL Squad)

Possible Future Projects

Where should we take this work next?
–With (roughly) data we have:
- 1. Relationship with relaxed/unrelaxed clusters (needs simulation measures from Rhea/Lucas?) ? Rhea/Lucas have been looking at this, e.g. 8th most massive substructure. Lucas doing Pt 1 NOW / SB student doing Pt 2 Later
- 1A. [Nina student leading; GM/SB/RSR/LK/YB involved] How do image-based and kinematic-based ICL particles relate?
- 2. [MM] Scaling relations of ICL (cf Fig9 Kluge2021): E.g. M_ICL vs. Stellar/halo mass, etc cluster mass / satellite galaxies etc. (We have M_ICL or L_ICL in Challenge#3Data as well as halo mass but not stellar mass of cluster *could reverse engineer?* or mass in satellites)
- 3. [MM] Light profiles? Explore ICL's self-similarity. Papers show ICL scales with mass of cluster. Can look in this mass range and expand if needed. Can investigate how much ICL lost due to image depth (SB limits) . Possibly comparing to DM profiles? (needs mass maps from simulations)

–Plus More Systems:
- 3. [??] Relationship of ICL with halo mass : Should be able to look at ~2 dex range (Hydrangea has a few x10^15M. So not large sample but they do exist. Magneticum can go down to 1x10^13…)
- 4. [??] What is Redshift dependence using observational techniques and true dependence

- 5. [MM] stellar populations! Colour/metallicity/ICL profiles (and how far we can reach with LSST SB limits). With mass and redshift and dynamical state. [Needs DUST]

I've consolidated these. I will estimate how to do the above with not many more systems than we have already analysed (maybe 120 systems compared to >180 before) and then could we make those measures in 3 months, i.e. by end August? Then who would lead 1-5?

2024/04/23 Meeting ICL Squad

Attendees: Annalisa. Mireia. Jesse. Rhea. Enrica. Chris Mihos. Marilena. Lucas. Johan. Lammim. Yolanda. Anthony. Rossella. Chris Collins. Garreth.

- Introductions
- Quick intro to this project
    - Related papers since ICL Squad#1 paper published (Added by SB but please add to): https://arxiv.org/abs/2401.08283 https://arxiv.org/abs/2402.17958 and https://arxiv.org/abs/2403.04897 .
- Update from Lucas:
    - Stellar mass - halo mass relation broken up by cluster relaxation (red in plot old-only accreted small amount since z~2), less relationship with M200_crit.
    - Also using Horizon-AGN. Comparing 11 categories suggested to related to cluster relaxation.
    - All particles or out to some radius? Out to M200_crit.
    - Focus on pointing out the F_BCG+ICL is important. M1-4 correlate well with F_BCG+ICL
    - What is the sample? What is the mass range? Inconsistencies with earlier work/between different simulations? Important to have a broader halo mass range in simulation analysis to say - F_BCG+ICL does depend on cluster relaxation. Can bootstrap broader samples to narrower and check that relationships hold. If relationships hold for broad mass range then can use simulations to show is broad universal thing that holds and then can study more narrow mass range in mock images/observations.
    - Also decouples any BCG correlation dependence there
    - Have data from Annalisa, thank you!
    - Just need data from Yannick :)

- Summary on original paper draft from Sarah (Viewing version available at this overleaf link https://www.overleaf.com/read/chcyhmzjdrrd#924873)
    - Could we use existing observational data to test this? Would be challenging owing to the different radii used in the different samples.

- Very weak relationship in Fig2. Could look at pearson correlations with specific kinds of measures - does 1 show a stronger relationship than another.
- If we compare observers measures also need to consider which band used by mock images. r-band used here. Yoli finds that is not the best band to trace the relaxed/unrelaxed cluster state.
- Fig 3 - needs look at correlations with specific kinds of measures
- How does Fig2 compare to Fig3? Fig 3 shows how simulation and observational measures compare as a function of cluster relaxation. Seem consistent. Fig 2a shows some relationship of F_8 with observed measure of F_BCG+ICL but SCATTER. Fig 2b shows no significant relationship of F_ICL with F_8.

A couple of long-winded follow-up comments by ChrisM:

- It seemed from the discussion that the definition of "relaxed" focused largely on z50, the redshift at which half the cluster mass was in place. Z50 is sort of a long-time measure of the accretion history. But to me, "relaxed" means something slightly different, I think of it in terms of dynamics, how settled down is the cluster in some vague sense. From that perspective, relaxation may be really about *recent* accretion, and that is a bit different from z50. Is it more appropriate (or at least worth exploring) whether the ICL properties depends on recent accretion? I could imagine looking at something like F_1Gyr or F_2Gyr, ie, the fraction of cluster mass accreted in the last 1 or 2 Gyr. or at least checking if F8 correlates with F_1Gyr or F_2Gyr…. **SB: Interesting question/thought process!**
- Also, it worries me a bit looking at current Fig 1 that while we see a trend in f(ICL+BCG) and f8, pretty much all the low f8 clusters are Magneticum and all the high f8 clusters are Hydrangea. Looking just at Magneticum, or just Hydrangea, or even just H-AGN, there is no correlation. Are we really sure we are not seeing some systematic difference between the simulation measures rather than a trend with f8? **SB: DEFINITELY COULD BE SO step 1 is to pin down those measures. Those plots were made with very early datasets and Magneticum and Horizon-AGN have been updated since and Hydrangea found to have a bug.**

LK: Great questions! To add to what Sarah has written, I've asked myself similar things about the timescales of accretion / what is "relaxed". It seems that depending on which ratio you choose you trace slightly different timescales, i.e., M12 is best for intermediate times (~ z50), while M14, M18 trace higher redshifts, i.e., correlate better with z30 or z20. As for Question 2, I've checked with the full set of clusters within Magneticum (~1500), and we recover the trend over the full range. The reason why for Fig. 1 this appears to be a split between Magneticum and Horizon-AGN is actually what prompted this idea of relaxation in the first place. We had first talked about taking "relaxed" clusters, so I had selected some particularly high ICL+BCG cases from the large set. By contrast, the clusters in Horizon-AGN are the few most massive nodes (due to boxsize), and thus tend to be more active (hence lower ICL+BCG).