The Luminosity – velocity dispersion relation of groups and clusters detected in the XXL and GAMA surveys

The clusters were selected in the northern region of the XXL survey from the overlap with the GAMA systems, as shown in Fig 1 (black box), within RA = 30.2 - 38.8 and Dec = -4.0 - 46.0 deg, totalling 16.1 deg² (note that the GAMA survey extends lower than this Dec range, but the completeness of the survey drops significantly below this range). The XXL clusters were selected to be the most secure clusters detected in the survey. The detection is fully described in Papadopoulos & et al. 2006, briefly, the clusters were detected using SExtractor and clusters with an extension likelihood >33 and detection likelihood >32 were classed as C1 clusters. All C1 clusters in the overlap region were then selected as our XXL sample.

The XXL and GAMA surveys

The L_\text{X} vs \sigma_{r} and L_\text{GAMA} vs \sigma_{v} relations are shown in Fig 2 (top plot and bottom plot respectively). The X-ray selected relation has been fully corrected for selection effects (black line and shaded grey region) using a method analogous to that presented in Giles+ 16. Due to a number of non-detections of GAMA selected systems in the X-ray, we were only able to derive upper limits on the luminosity for these systems. Therefore, we use the LIRA package (Sereni 2016) to fit for the L_\text{GAMA}\rightarrow\sigma_{v} relation (given by the green line in the bottom plot of Fig 2).

We find that bias-corrected L_\text{X} vs \sigma_{v} and the L_\text{GAMA} vs \sigma_{v} relation are statistically consistent. The scatter of the L_\text{GAMA} vs \sigma_{v} is 1.5 times larger than the L_\text{XXL} vs \sigma_{v} relation (significant at the 2σ level). A recent study by Andreon+16 found that the scatter of the luminosity-mass (LM) relation of their optically selected sample was 2.7 times larger than the relation determined from the X-ray selected REXCESS sample (Pratt et al. 2009), including the cluster core and correcting for X-ray selection. However, our results do not show this significant increase in the scatter as found in Andreon+16. We note however that we are not comparing the LM relation between X-ray and optically selected clusters as in Andreon+16.

The L-\sigma relation

Our optically selected cluster sample contains 15 GAMA sources that do not have significant cluster emission (e.g. Fig 3, left plot). One possible explanation would be if the gas within the cluster has not yet reached the virial temperatures required to emit at X-ray wavelengths, suggesting that the undetected GAMA systems are young and still in the process of forming. Cosmological simulations have shown that the apparent magnitude gap (m12) between the brightest cluster galaxy (BCG) and second brightest cluster galaxy can give an indication of the cluster age (e.g. Dariush+10; Cui+11; Raouf+14,16). Figure 3 (right) plots the distribution of m12 as a function of the total group r-band luminosity. There appears to be a clear separation of X-ray detection rate of GAMA systems as a function of m12, whereby all GAMA selected systems below m12=0.45 have no corresponding extended X-ray emission.

The GAMMA selected sample was chosen within the same region and to have a minimum group luminosity of L_\text{X}\geq 1.7\times10^{45} erg/s. The luminosity limit was chosen to provide a comparable sample size to the C1 XXL sample. We employed an additional redshift limit on the GAMA selection since the estimate of the luminosity has a greater level of bias above a redshift of 0.2 (see Fig 10 in Robotham++11). By considering the sample selection over the same area, we do not rely on comparisons of external datasets to probe the true range of diversity in X-ray and optically selected clusters. We explore the soft-band luminosity – velocity dispersion relations for the XXL selected (L_\text{XXL} vs \sigma_{v}) and GAMA (L_\text{GAMA} vs \sigma_{v}) relations.

The GAMMA selected upper limits of L_\text{GAMA} on the X-ray luminosity compared to X-ray selected REXCESS sample (Andreon+16). By considering the sample selection over the same area, we do not rely on comparisons of external datasets to probe the true range of diversity in X-ray and optically selected clusters. We explore the soft-band luminosity – velocity dispersion relations for the XXL selected (L_\text{XXL} vs \sigma_{v}) and GAMA (L_\text{GAMA} vs \sigma_{v}) relations.

Low surface brightness optically selected clusters

The investigation of high-mass galaxy clusters has had a rich history. Comparatively however, the lower-mass galaxy group population remains largely uncharted territory. A key question is the degree to which groups differ from being scaled-down versions of higher mass clusters, motivated by the expectation that non-gravitational processes (AGN and SN feedback) are more effective in the group-scale regime. The dominance of feedback in low-mass systems leads to large scatter in X-ray luminosity at fixed mass. The amount of, and mass dependence of this scatter are important clues to the nature of the feedback physics. Probing the scatter to gain insight into feedback physics is complicated due to the biases involved when selecting cluster samples. It is well known that X-ray selected cluster samples suffer from both Malmquist and Eddington bias, and while recent efforts have been made to correct for these biases when modelling scaling relations (e.g. Stanek+06; Pacaud+07; Mantz+10; Andreon & Bégué 2012; Lovisari+15; Giles+16, 17), they require the use of selection functions based on some prior knowledge of the range of cluster properties. Recent studies of optically selected clusters show an increased scatter in X-ray luminosity compared to X-ray selected samples (Andreon+16). The resulting mass calibration based on a mass-observable selection scatter will therefore be effected, as will knowledge of selection functions, needed for the inference of cosmology from cluster samples.

To this end, we have constructed two samples of clusters, one sample constructed based on their X-ray emission using the XXL survey (Pierce+16), and the second based on their optical luminosity, using the Galaxy and Mass Assembly (GAMA, Driver+11) survey. Both samples are constructed from surveys in overlapping areas allowing for direct comparisons of the type of systems selected.

The L-\sigma relation shows the XXL image of a GAMA selected cluster with no significant X-ray emission. The black circles show the positions of individual GAMA galaxies, and the red circle highlighting the BCG. The right figure plots the r-band magnitude gap against optical luminosity for GAMA selected sample. Black squares highlights clusters with significant X-ray emission.