WHERE IS THE CENTER OF MASS IN GALAXY GROUPS?

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Above: Images of three galaxy groups observed in the COSMOS field with Subaru (R,z,K bands), showing the varying level of agreement between different tracers of the halo center. The tracers coincide in the groups to the left and right, while in the middle group, there is disagreement between the brightest and most massive galaxies, and the choice of center depends on the radius searched. Green contours show the X-ray emission and the green circle shows the X-ray peak. Yellow circles show the iteratively determined center of stellar mass of member galaxies, while red circles show the luminosity-weighted center (834W/m^2 band). Squares show the most massive galaxy (green, yellow) or the most luminous galaxy (red) within the NPW scale radius of the correspondingly-colored circle. Diamonds show the most massive (yellow) and most luminous (red) galaxy within R200 of the correspondingly-colored circle. Cyan stars are placed at the visually-labeled center selection. From left to right, these groups have z = 0.320, 0.328, 0.372; Lx = 3x10^48, 5x10^48, 1x10^49 erg/s (0.1-2.4 keV, rest-frame); and halo masses 1.6x10^14, 4.2x10^14, 8.7x10^14/M. Each image is 180" on a side, which at the given redshifts corresponds to a physical scale of 630, 1100, and 920 kpc.

Introduction
It is important to be able to determine the center of mass of galaxy groups and clusters for a variety of studies including finding halos, weighing them through gravitational lensing or satellite dynamics, understanding the environmental dependence of galaxy evolution, and determining how galaxies are distributed with respect to dark matter. Typically, it is assumed that the brightest galaxy in a group or cluster sits at the center of the halo potential, but this assumption is not always valid. Here we aim to determine which tracer best identifies the halo center by measuring the weak lensing shear signal from galaxy groups stacked on different candidate centers.

COSMOS Group Catalog
We analyze the X-ray selected galaxy group catalog from the COSMOS field, consisting of 211 groups with masses in the range 10^{13}-10^{14} M_☉ and redshifts 0 < z < 1. Member galaxies are selected using photometric redshifts derived from over 30 ultraviolet, optical, and infrared bands. By incorporating the full probability distribution function of the photometric redshifts, we obtain a galaxy member catalog that is ~90% complete and ~70% pure when checked against a subsample with spectroscopic redshifts. Imaging with the Advanced Camera for Surveys aboard the Hubble Space Telescope provides precise shape measurements for weak lensing of stacked galaxy groups.3,4

Results
Our preliminary analysis indicates that the data are capable of resolving offsets between different tracers separated by distances on the order of 100 kpc. The center of mass of groups appears to most closely agree with the most massive galaxy within R200 of the X-ray center. The centroids weighted by stellar mass or by luminosity of member galaxies produce discrepant results, indicating that they are poor tracers of the center of total mass. The distribution of offsets between candidate centers (above, left) shows reasonable agreement between the positions, but some comparisons show long tails indicating a population of groups that may be unrelaxed. It will be interesting to correlate these offsets with other indicators of merger activity.

We can also study the radial distribution of galaxies and compare their concentration with that of the dark matter. By selecting various populations of galaxies we can learn about the role of halos and other group members in galaxy evolution. For example, the plot at the bottom right shows the familiar result that quiescent red galaxies are more centrally concentrated than blue star forming galaxies.

Summary and Outlook
We can use weak lensing to determine the spatial separation between baryonic tracers and the halo center. With our catalog of group member galaxies and locations of halo centers, we will be able to place constraints on the mass-concentration relation and the halo occupation distribution, as well as study the role of environment in galaxy evolution.

Weak Lensing Analysis
To obtain a weak lensing signal in the mass range of these groups requires stacking, which brings the benefit of increasing signal as well as relaxing the assumption of spherical symmetry in individual groups, since only the average group is assumed to be spherical. The lensing signal is measured in radial bins around a chosen center of the stacked groups, and the signal is maximized at the true center of mass. If the wrong center is chosen, the lensing signal tends to decrease near the center.

Candidate Centers
We define several “centers” of galaxy groups:
- X-ray center
- Brightest galaxy within R200 of X-ray center
- Brightest galaxy within R500 of X-ray center
- Most massive galaxy within R200 of X-ray center
- Most massive galaxy within R500 of X-ray center
- Stellar mass-weighted centroid (CM)
- Luminosity-weighted centroid (CL)
- Redshift: 0.56
- Concentration: 3.97
- Redshift: 0.58
- Concentration: 3.93
- Redshift: 0.58
- Concentration: 3.93

Below: Radial distribution of member galaxies around M200(R200). Colors indicate different populations: all member (black), quiescent (red), intermediate (green), star-forming (blue).

References