We measured gas masses for the 30 richest SDSS redMaPPer clusters using newly acquired Chandra x-ray data. We develop a likelihood framework that accounts for our cluster selection function to measure the richness-mass and gas mass-mass scaling relations and their scatter. We find that the weak lensing mass calibration of SDSS clusters in Simet et al. 2016 is fully consistent with the weak lensing mass calibrations of x-ray clusters in the Weighing the Giants sample (Mantz et al. 2016). Combining the SDSS redMaPPer weak lensing calibration, the Weighing the Giants calibration of the gas mass-mass scaling relation, and our Chandra data, we are able to place a 95% upper limit on the scatter in the richness-mass relation of $\tau_{in,\lambda} < 0.459$ at a pivot mass of $M_p = 5.67 \times 10^{14} M_\odot h^{-1}$. Mass-richness priors are taken from the weak lensing mass calibration of the SDSS redMaPPer clusters. The solid blue band is our best fit relation with the 68% confidence region. We model our selection function with a Poisson distribution and the distribution $P(\lambda_1, M_{gas,1} | M)$ as a bivariate Gaussian distribution. We place informative priors on the mean of the mass-richness relation and the gas mass-mass scaling relation. Mass-richness priors are taken from the weak lensing mass calibration of the SDSS redMaPPer clusters in Simet et al. 2016 shown on left below (Melchior et al. 2017). Gas mass-mass priors are taken from the weak lensing mass calibration of x-ray clusters in the Weighing the Giants sample in Mantz et al. 2016 shown on right below.

### 30 Second Summary

- We measured gas masses for the 30 richest SDSS redMaPPer clusters using newly acquired Chandra x-ray data.
- We developed a likelihood framework that accounts for our cluster selection function to measure the richness-mass and gas mass-mass scaling relations and their scatter.
- We find that the weak lensing mass calibration of SDSS clusters is fully consistent with the weak lensing mass calibrations of x-ray clusters in the Weighing the Giants sample (Mantz et al. 2016).
- Combining the SDSS redMaPPer weak lensing calibration, the Weighing the Giants calibration of the gas mass-mass scaling relation, and our Chandra data, we are able to place a 95% upper limit on the scatter in the richness-mass relation of $\tau_{in,\lambda} < 0.459$ at a pivot mass of $M_p = 5.67 \times 10^{14} M_\odot h^{-1}$.

### I. Data

- We place informative priors on the mean of the mass-richness relation and the gas mass-mass scaling relation.
- Mass-richness priors are taken from the weak lensing mass calibration of the SDSS redMaPPer clusters in Simet et al. 2016 shown on left below (Melchior et al. 2017). Gas mass-mass priors are taken from the weak lensing mass calibration of x-ray clusters in the Weighing the Giants sample in Mantz et al. 2016 shown on right below.

### II. Likelihood Model and Validation

- Cosmological constraints from optical survey data require a detailed understanding of the richness-mass relation of galaxy clusters.
- We measure the gas mass of the 30 richest clusters in SDSS redMaPPer using newly acquired Chandra data.
- This sample of richness selected clusters represents the first complete sample of redMaPPer clusters with high quality x-ray data, allowing us to place constraints on the scatter of the richness-mass relation for the first time.

#### Likelihood

We use weak lensing priors to anchor our cluster masses. The probability that each cluster has their observed richness $\lambda_i$, the second richest cluster has richness $\lambda_2$, etc.

#### Scaling Relations - Power Laws in Mass

- $\langle \lambda | M_{200m} \rangle = \lambda_0 \left( \frac{M_{200m}}{M_{peak,\lambda}} \right)^{\alpha_\lambda}$
- $\sigma_\lambda^2 = \langle \lambda | M \rangle^2 \sigma_{in,\lambda}^2$
- $\langle M_{gas} | M_{200m} \rangle = M_{gas,0} \left( \frac{M_{200m}}{M_{peak,mg}} \right)^{\beta_{mg}}$
- $\sigma_{mg}^2 = \langle M_{gas} | M \rangle^2 \sigma_{in,Mg}^2$

#### Validation

We validate our likelihood analysis using 100 synthetic data sets. We check that the probability that our input parameters fall within the 68% confidence contour is 68%. The figure on the left repeats this check for many confidence intervals between 2% and 98%.

### III. Results

- The SDSS redMaPPer and Weighing the Giants scaling relations are fully consistent with each other.
- Neither scaling relation is able to improve upon the other when combined with out data set. The posteriors are identical to their priors.

### IV. Conclusions

- We have shown that the mass calibrations from SDSS redMaPPer weak lensing and Weighing the Giants x-ray samples are consistent within reported uncertainties.
- We have placed a 95% upper limit on the scatter in the richness-mass relation of $\tau_{in,\lambda} < 0.459$. 

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**References**