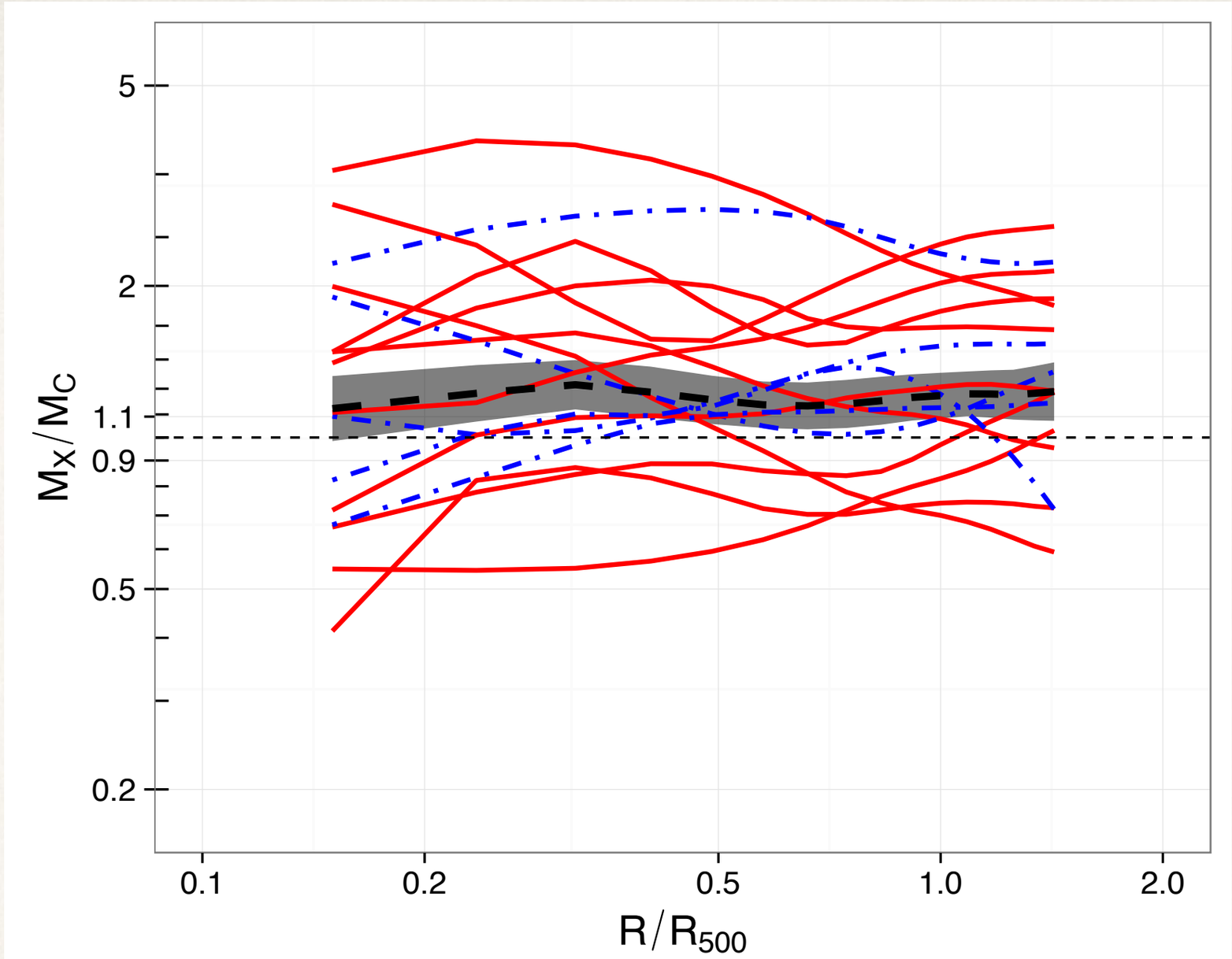


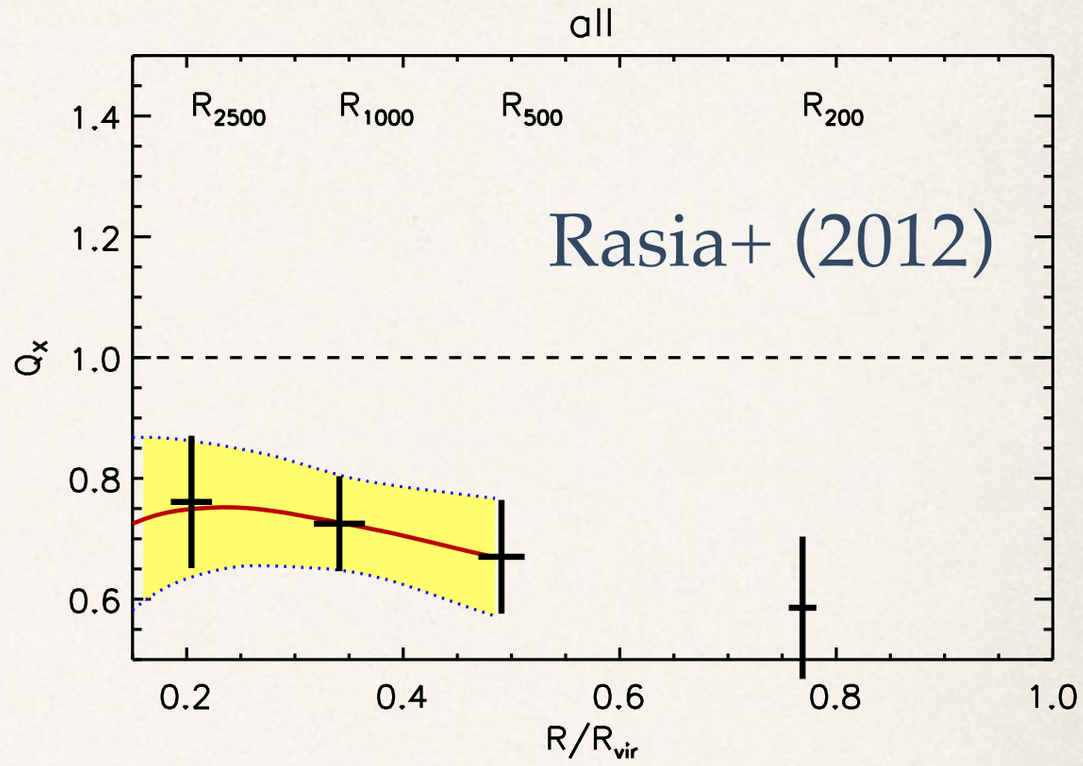
Hydrostatic and Caustic Mass Profiles

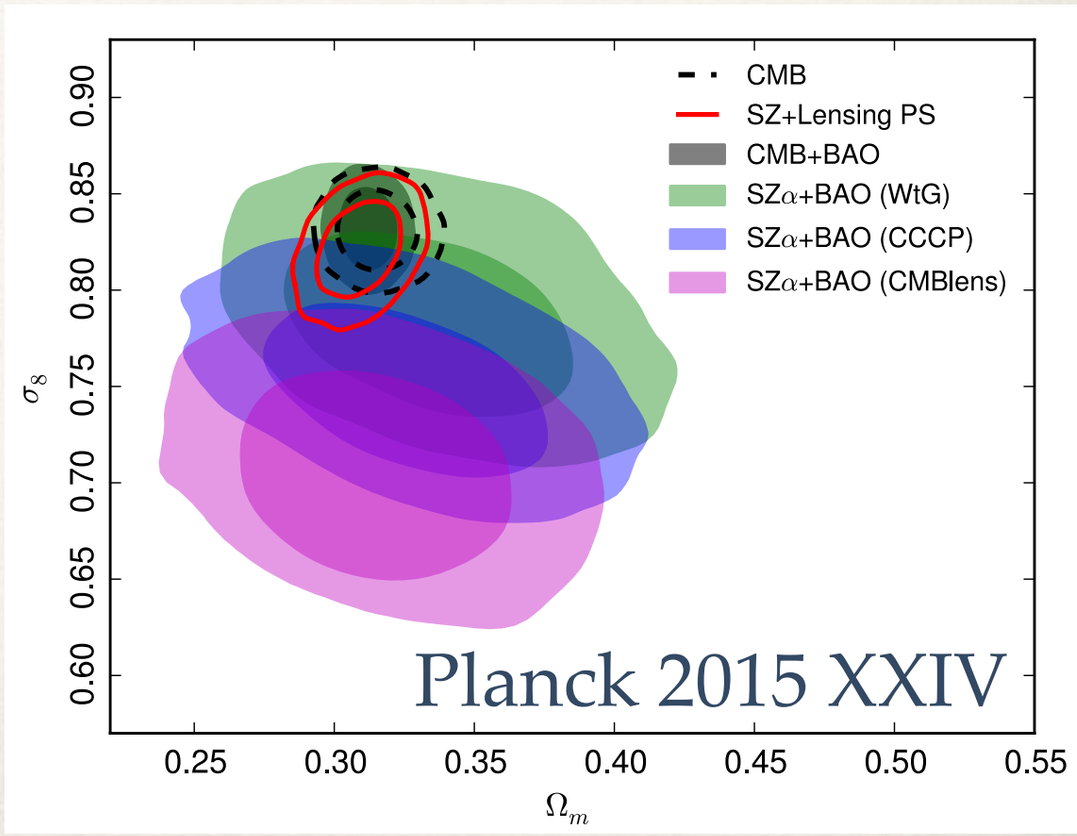
Ben Maughan, Paul Giles, Ken Rines, Antonaldo Diaferio, Margaret Geller, Max Bonamente

University of Bristol

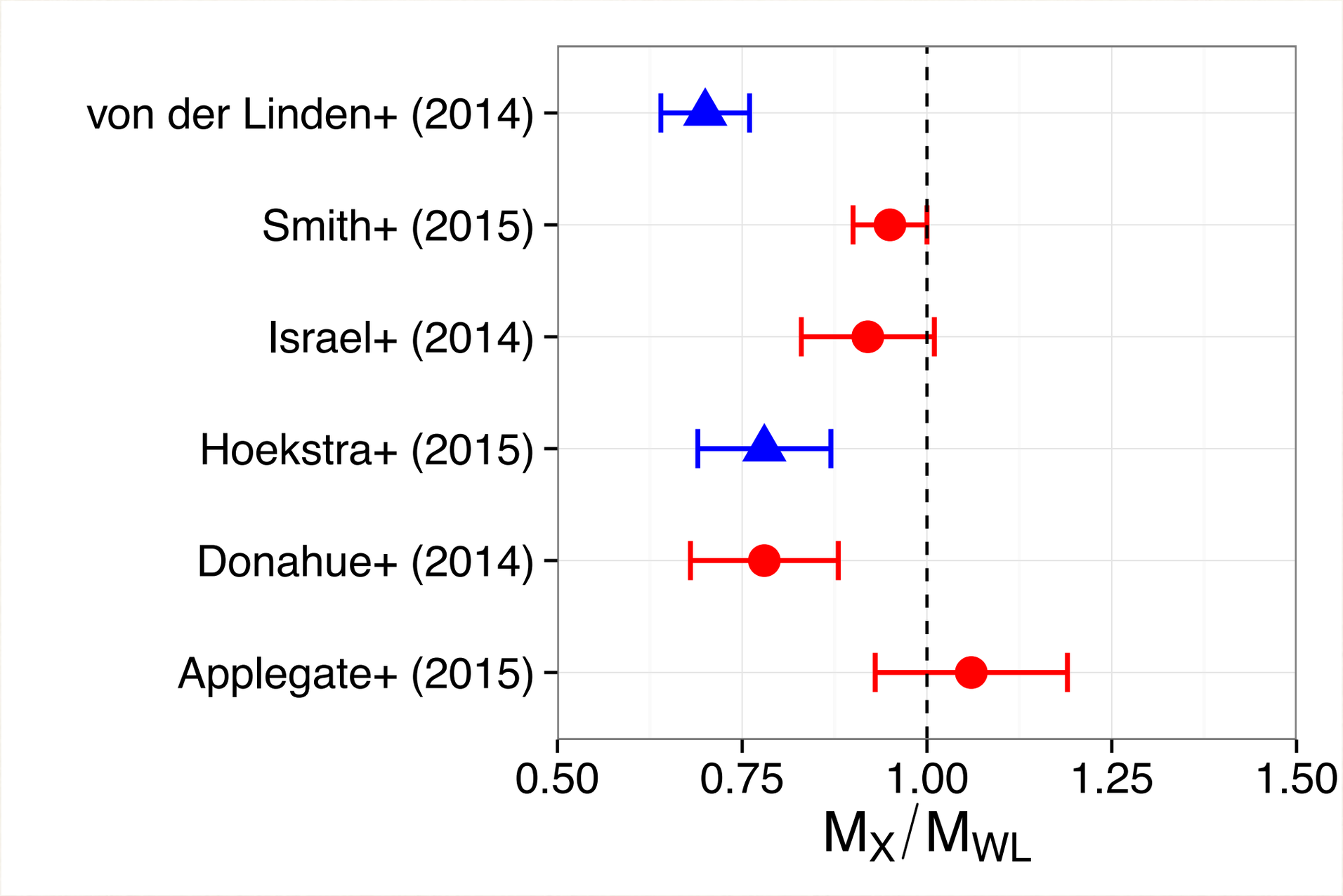
Hydrostatic Bias

- Simulations suggest hydrostatic masses underestimated
  - $M_X / M_{TRUE} = 0.7$ - 0.8
- Ratio of ~0.6 would reconcile Planck cosmological results





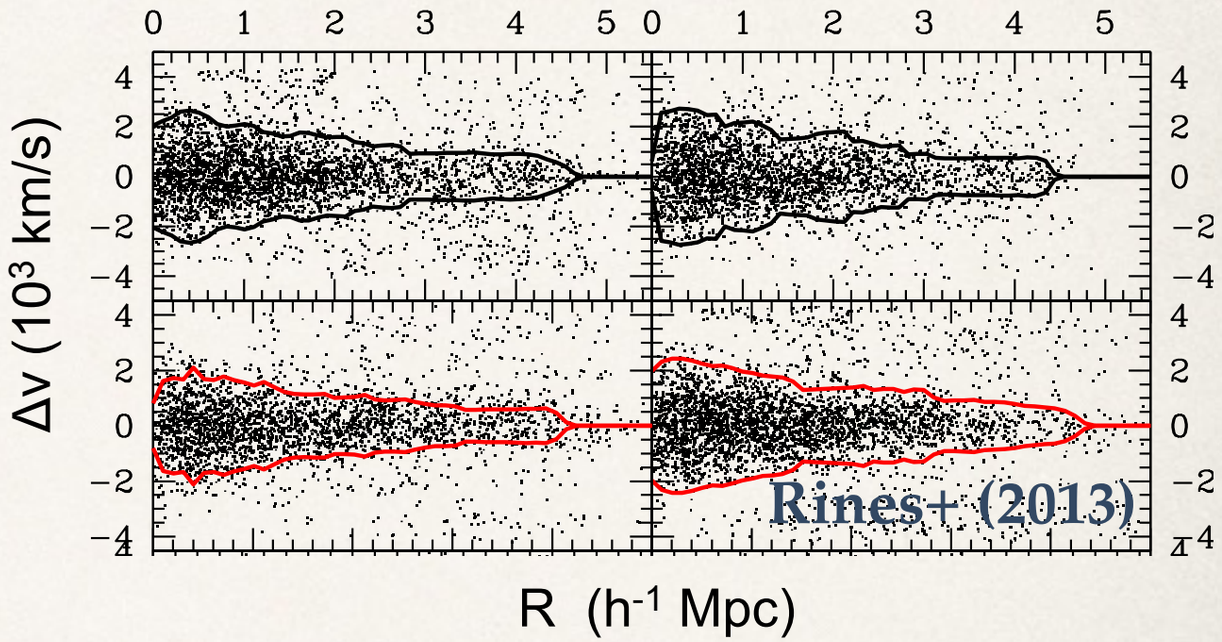
Lensing Calibration

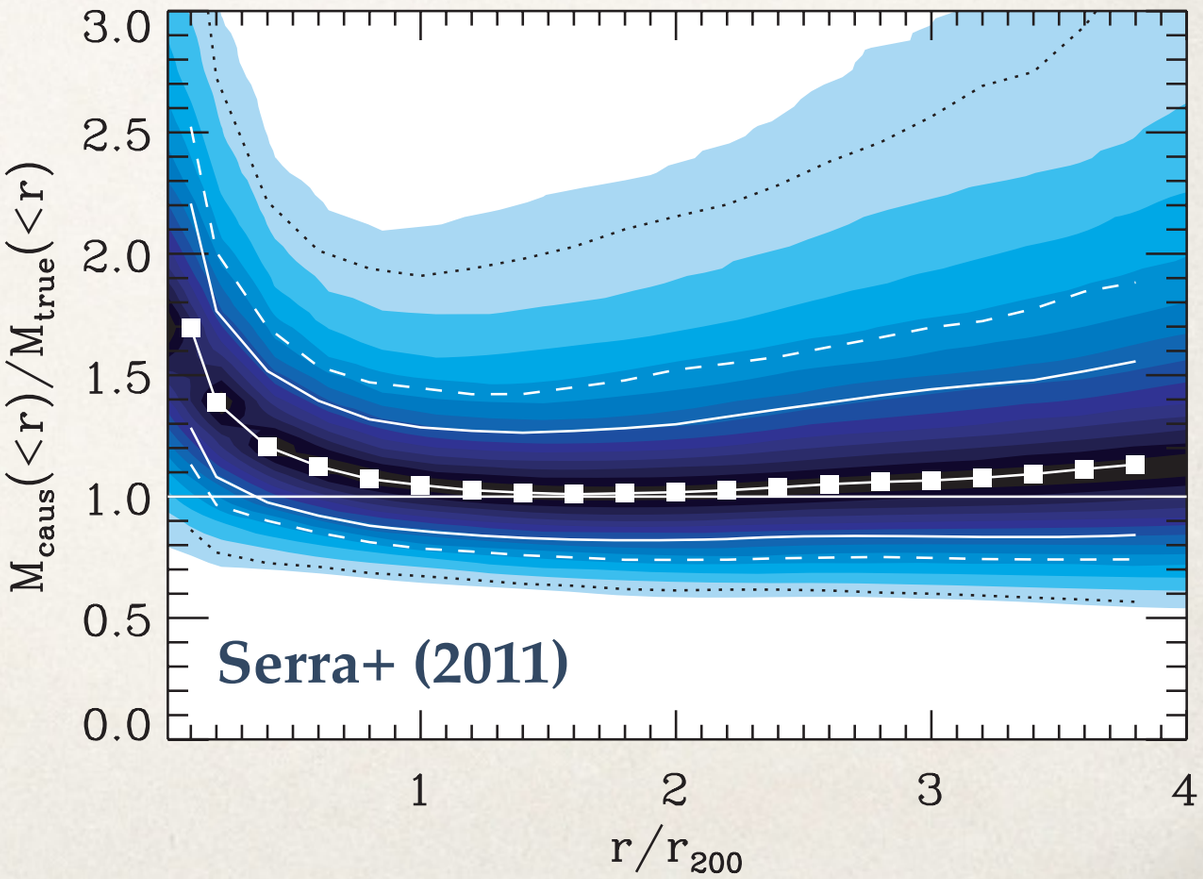


- Comparisons of WL and X-ray masses are mixed

Caustic Masses

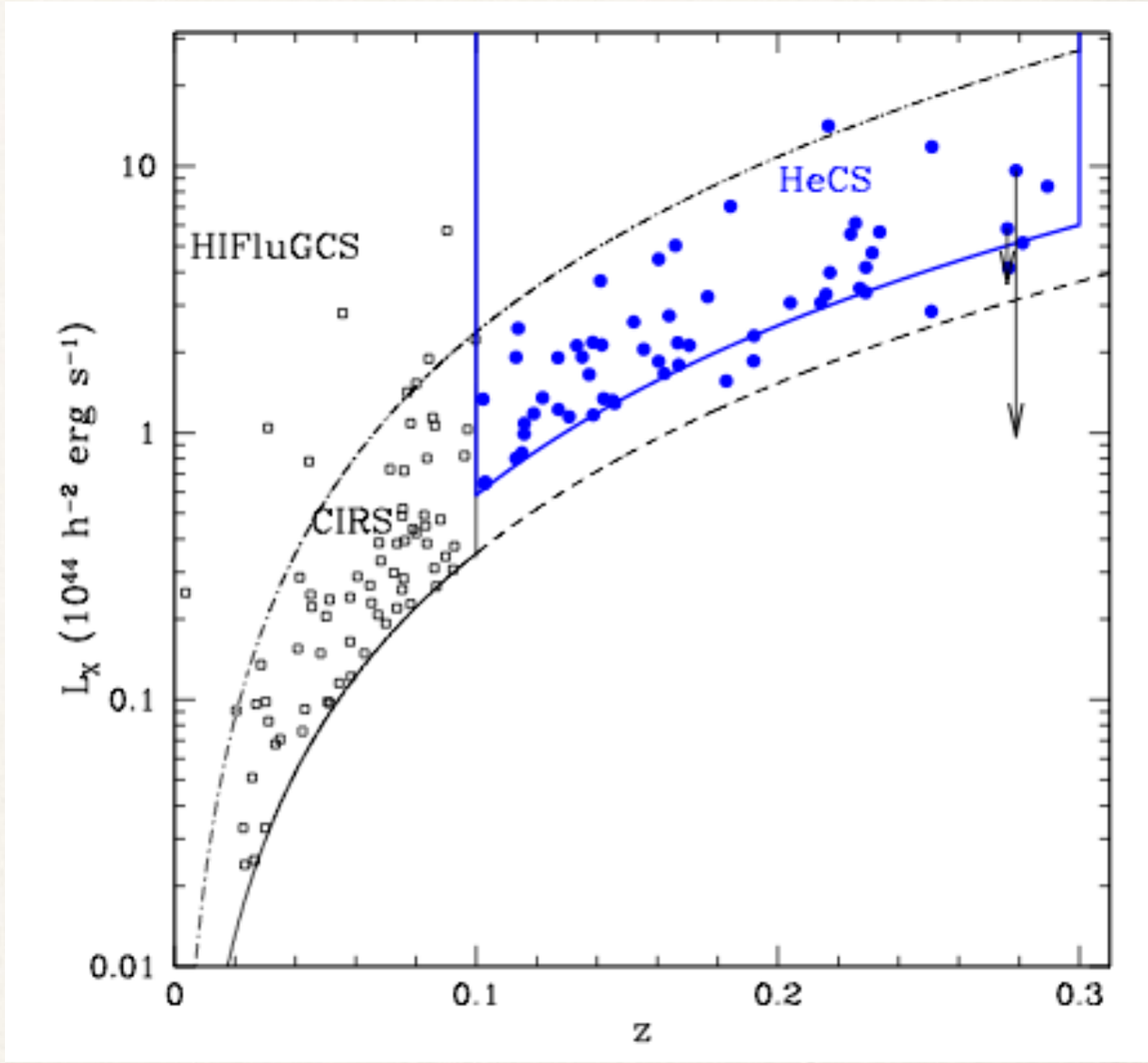
- Trace escape velocity profiles
- Effective to >R200
- Expected to overestimate true mass by ~20% at R500
- **Prediction: $M_X/M_C \sim 0.7$**





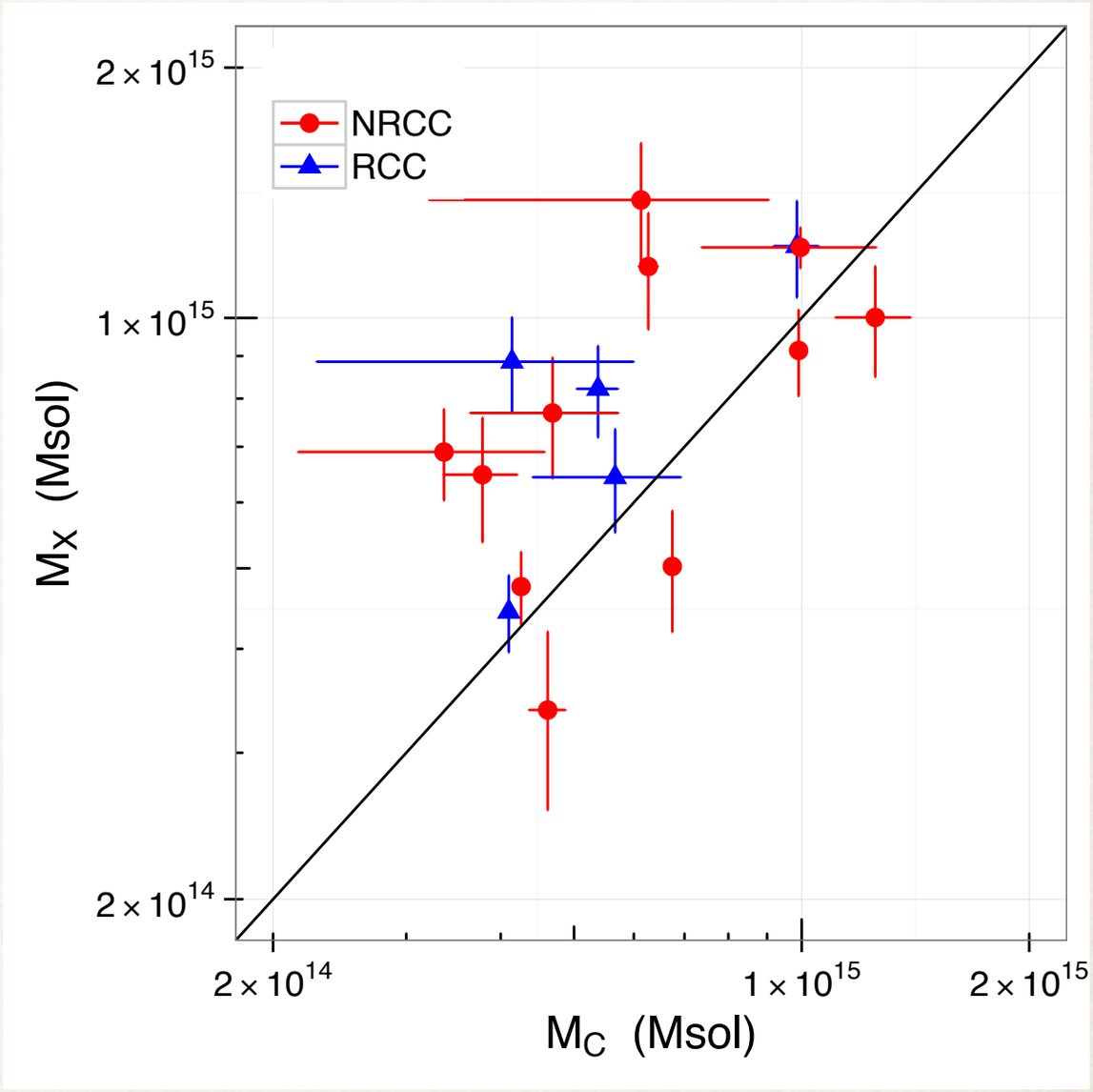
CHeCS

- Chandra observations of HeCS
  - 16/50 clusters
  - X-ray flux limited
  - $0.15 < z < 0.30$
- Hydrostatic masses from Giles+ (submitted)
- Caustic masses from Rines+ (2013)
  - ~200 galaxies per cluster



Hydrostatic Vs Caustic Masses

- Mass profiles measured independently
  - neither assume parametric form for M(R)
- Compare using **X-ray R500** (not important)



Hydrostatic Vs Caustic Masses

- Model the hydrostatic and caustic masses as coming from a normal distribution (in log space)
  - each with bias and scatter relative to "true" mass

$$\mu_{\rm X} \sim \mathcal{N}(\mu + \kappa_{\rm X}, \delta_{\rm X}) \qquad \mu_{\rm C} \sim \mathcal{N}(\mu + \kappa_{\rm C}, \delta_{\rm C})$$

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- Include measurement errors

$$\hat{\mu}_{\rm X} \sim \mathcal{N}(\mu_{\rm X}, \sigma_{\rm X}) \qquad \hat{\mu}_{\rm C} \sim \mathcal{N}(\mu_{\rm C}, \sigma_{\rm C})$$

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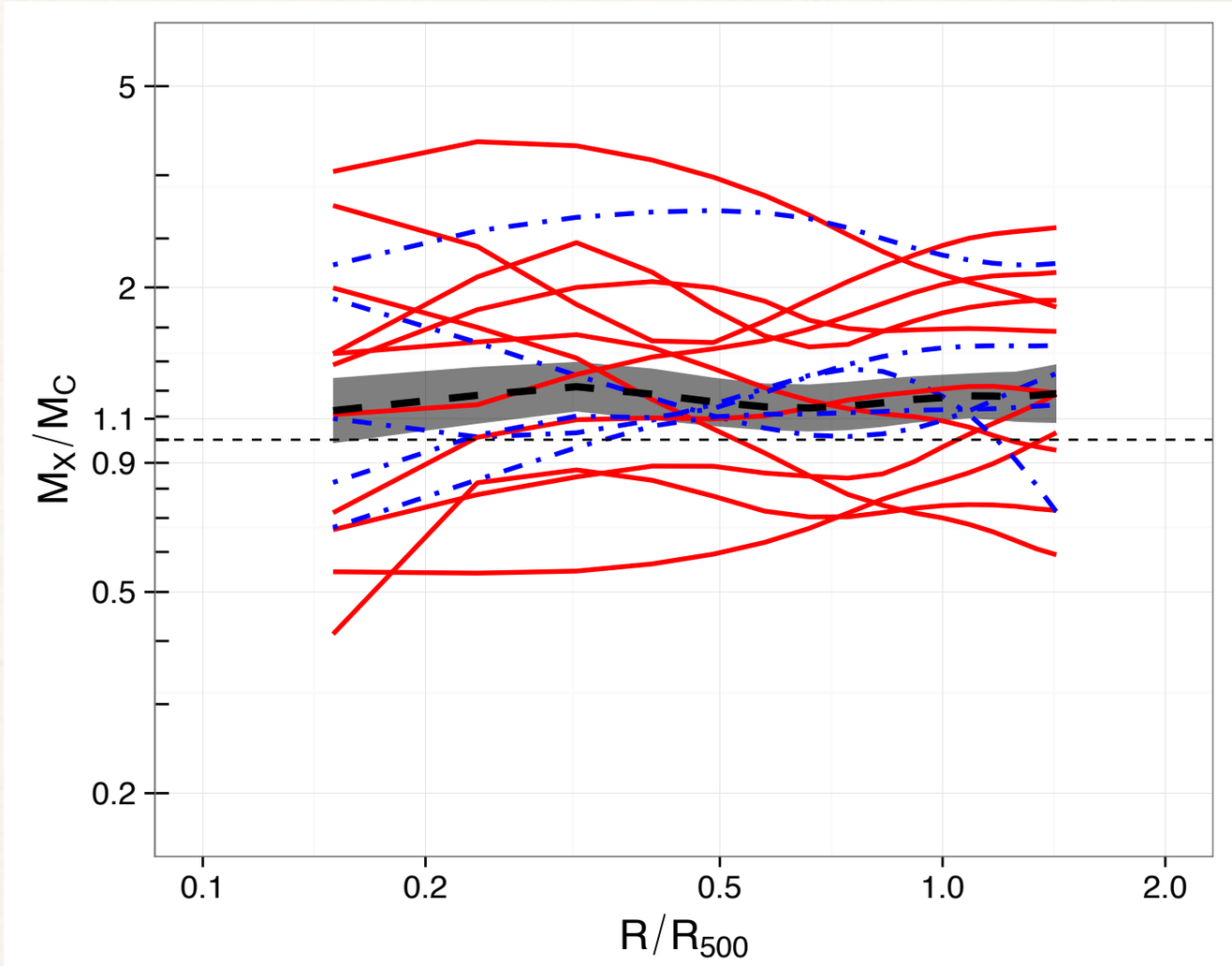
- Scatter and bias degenerate, but combinations can be constrained

$$\kappa = \kappa_{\rm X} - \kappa_{\rm C} = \log_{10}\left(\frac{M_{\rm X}}{M_{\rm C}}\right) \qquad \delta = \sqrt{\delta_{\rm X}^2 + \delta_{\rm C}^2}$$

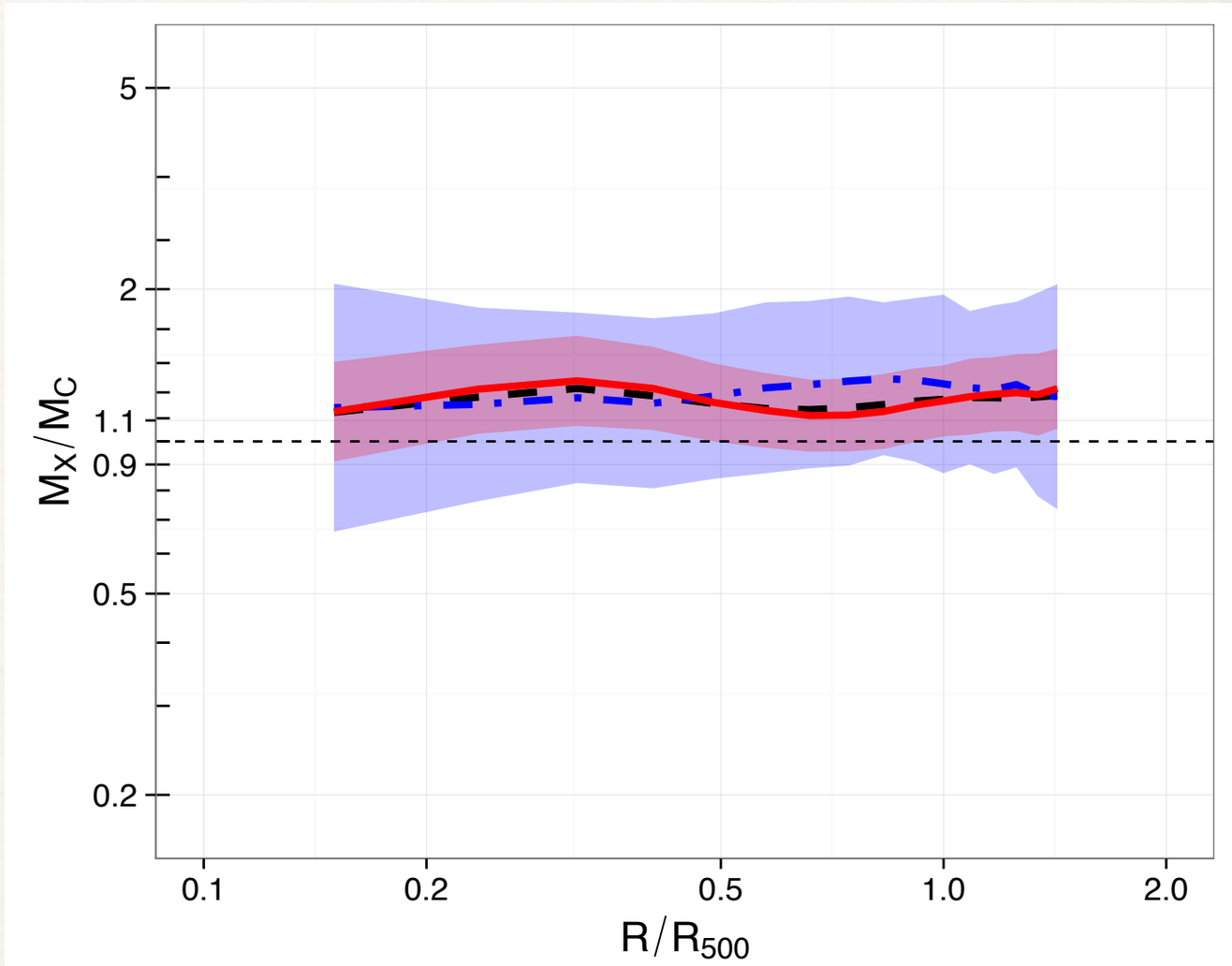
Hydrostatic Vs Caustic Masses

- Compute profile of M_X/M_C
- Masses agree to within ~20% at all radii
- $M_X/M_C = 1.20 +/- 0.12$ within X-ray R500
- $M_X/M_C = 1.15 +/- 0.12$ within 1 Mpc



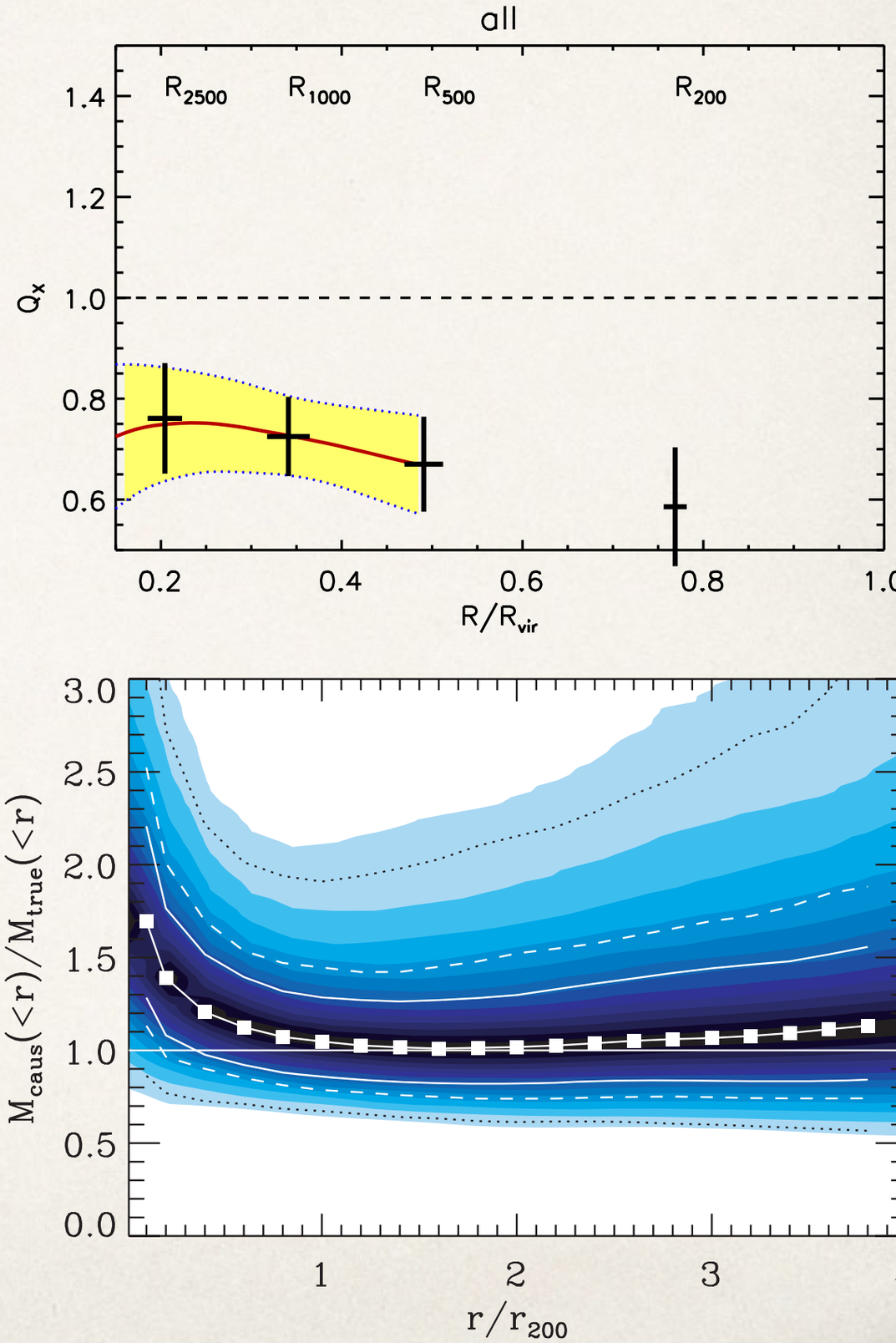
Hydrostatic Vs Caustic Masses

- No evidence for dependence on X-ray morphology
  - weak constraints
- Scatter is 23 +/- 12% at R500 (full sample)
  - ~30% scatter expected in caustic masses



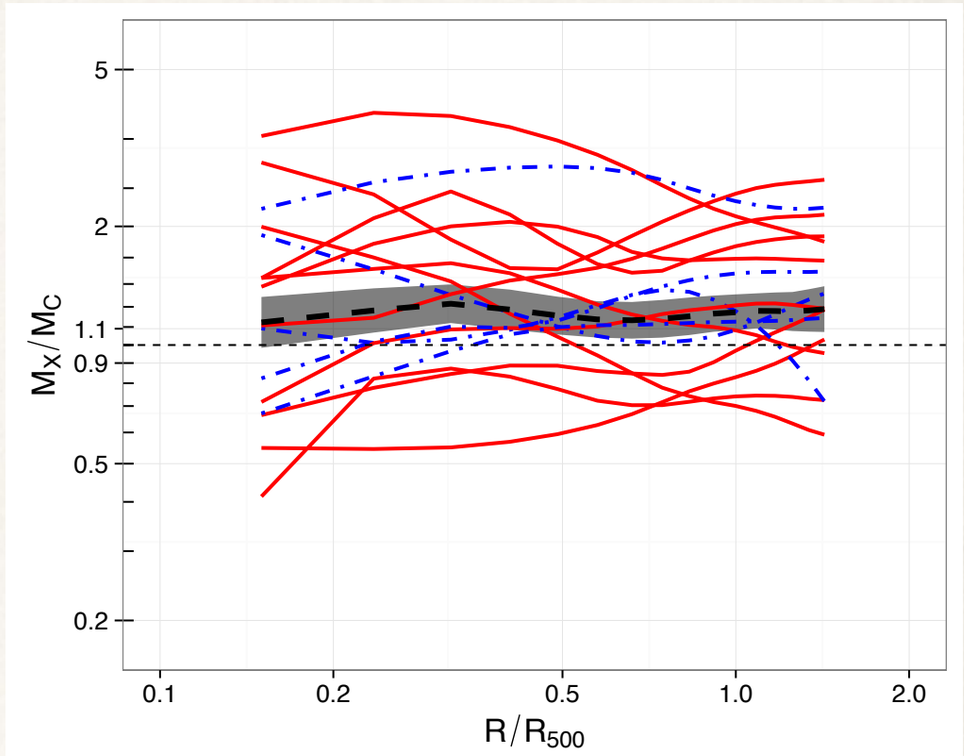
Limits on Biases

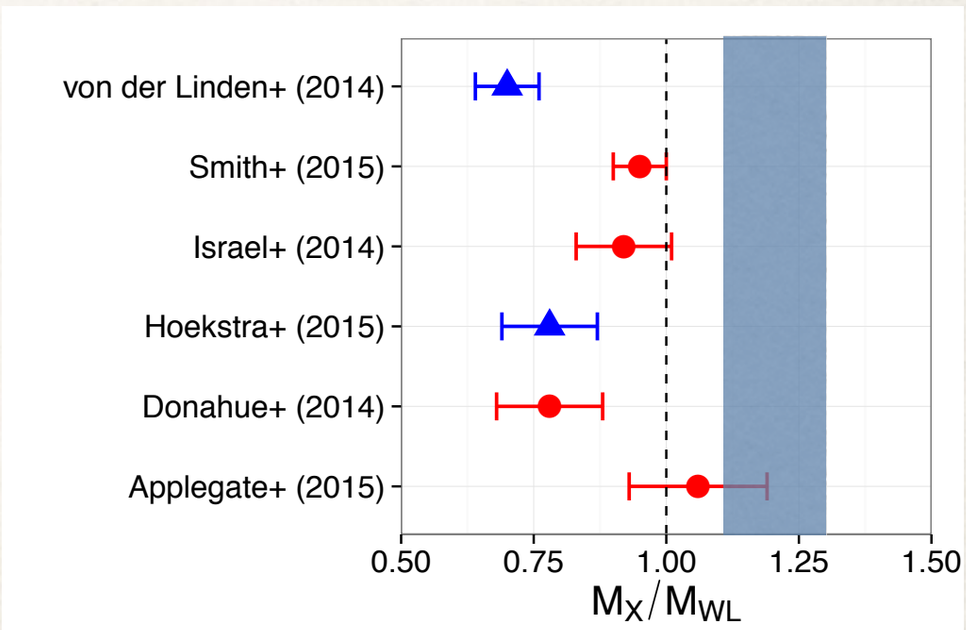
- Expectations:
  - $M_X/M_{TRUE} \sim 0.8$
  - $M_C/M_{TRUE} \sim 1.2$
  - $M_X/M_C \sim 0.7$
- **We find $M_X/M_C > 0.9$ at 3σ**
- Suggests small (~ zero) hydrostatic bias
- Smaller-than-expected caustic bias?



Summary

- $M_X/M_C = 1.2 +/- 0.1$ at R500
  - ~25% intrinsic scatter
- Disfavours large hydrostatic bias
- Chandra completion of full CHeCS 50 clusters underway





See arXiv:1511.07872

Summary

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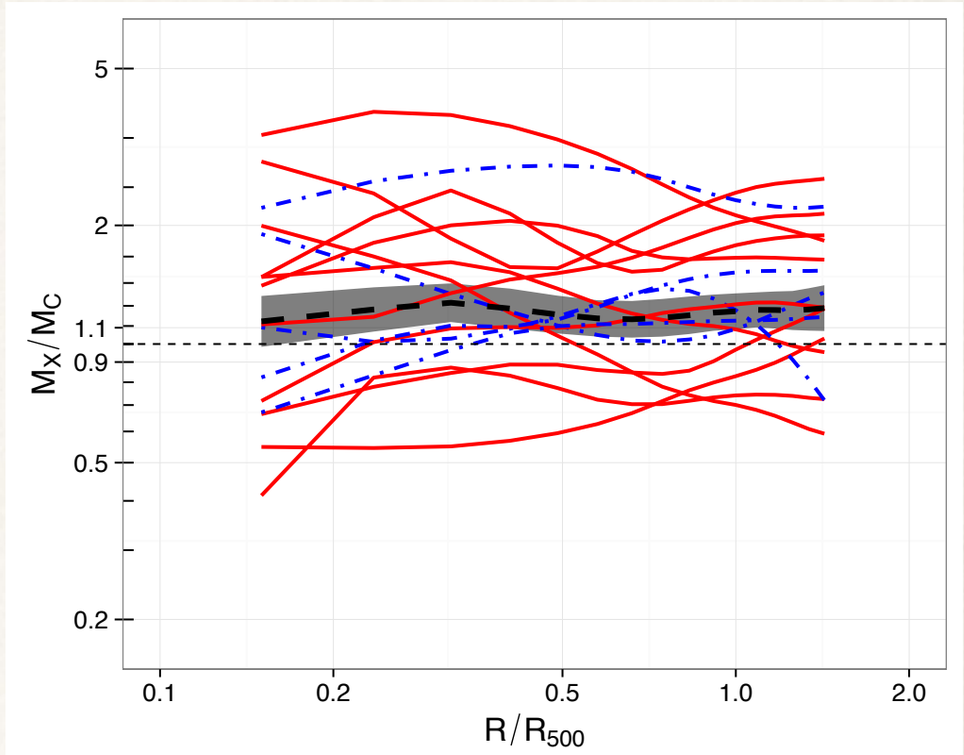
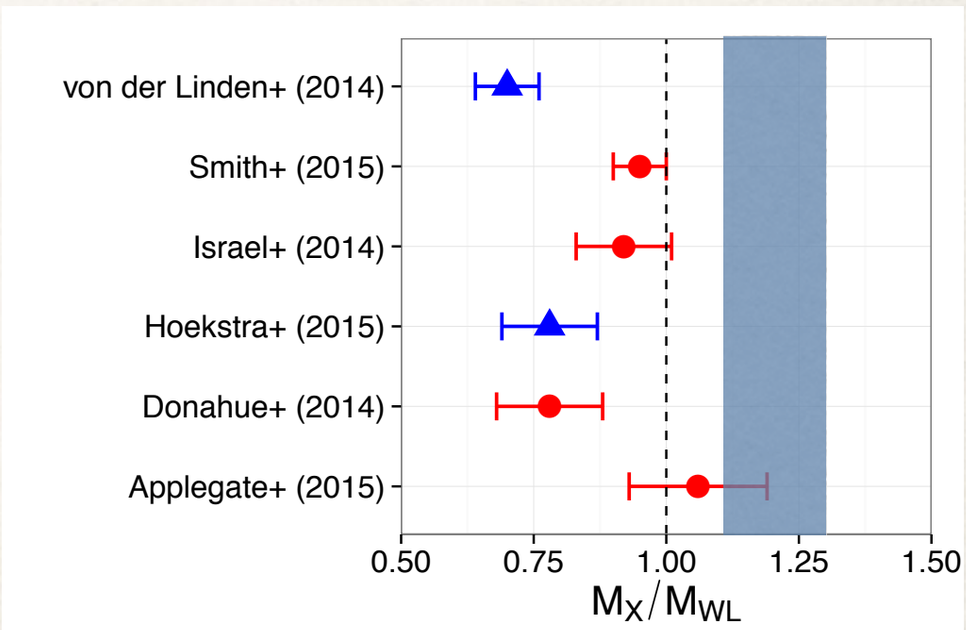
X-ray mass bias
is probably quite little.
More data to come.

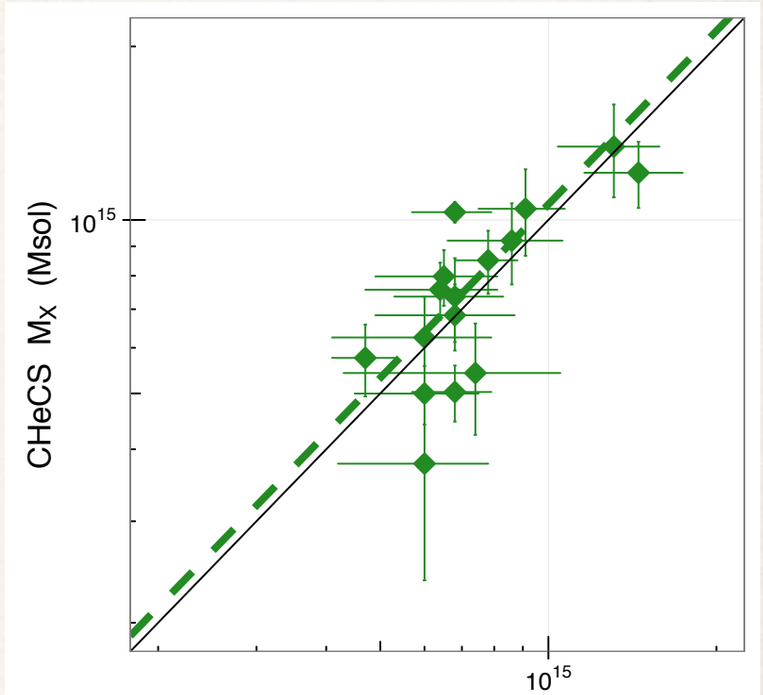


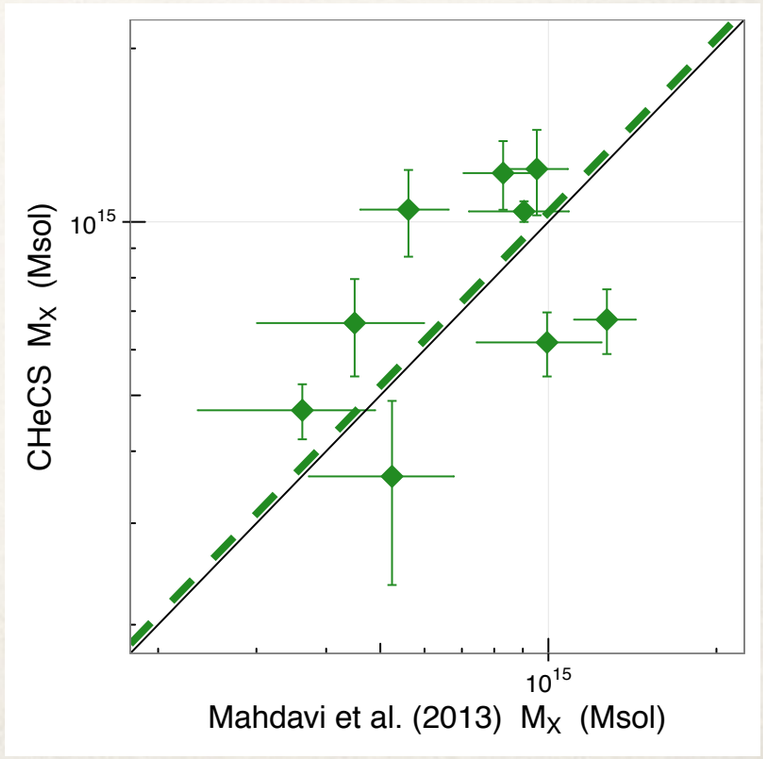


See arXiv:1511.07872

Cross-CHeCS

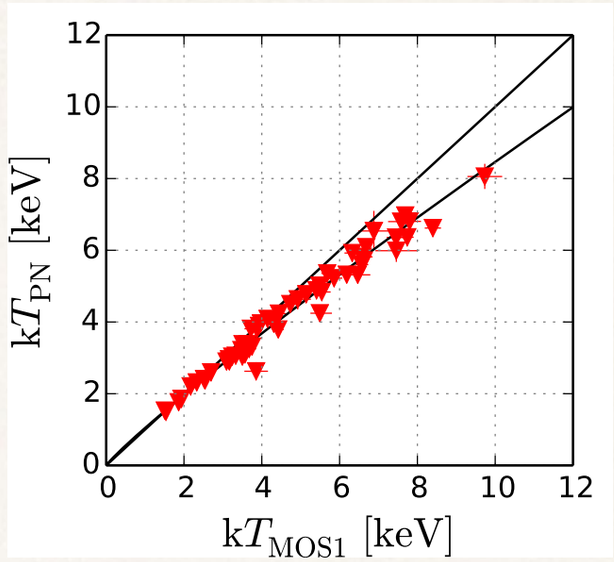
- Compare our hydrostatic masses with literature
- Recompute in other sample's R500
- $M_{CHeCS}/M_{Martino} = 1.06 +/- 0.07$
- $M_{CHeCS}/M_{Mahdavi} = 1.04 +/- 0.09$

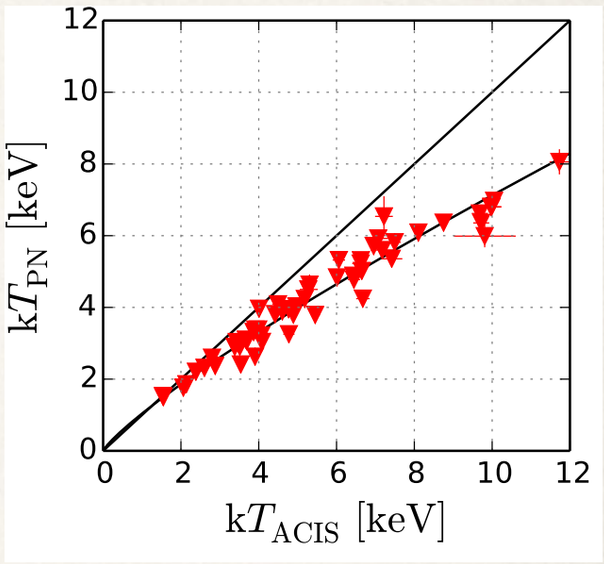




X-ray Calibration

- Chandra T higher than XMM
  - (but PN and MOS not consistent either)





Schellenberger+ (2015)

- Chandra masses ~15% higher
  - XMM would give $M_X/M_C = 1.0$
- But see Martino+ (2014)