Search for Galaxy-ICM Interactions in Rich Clusters of Galaxies

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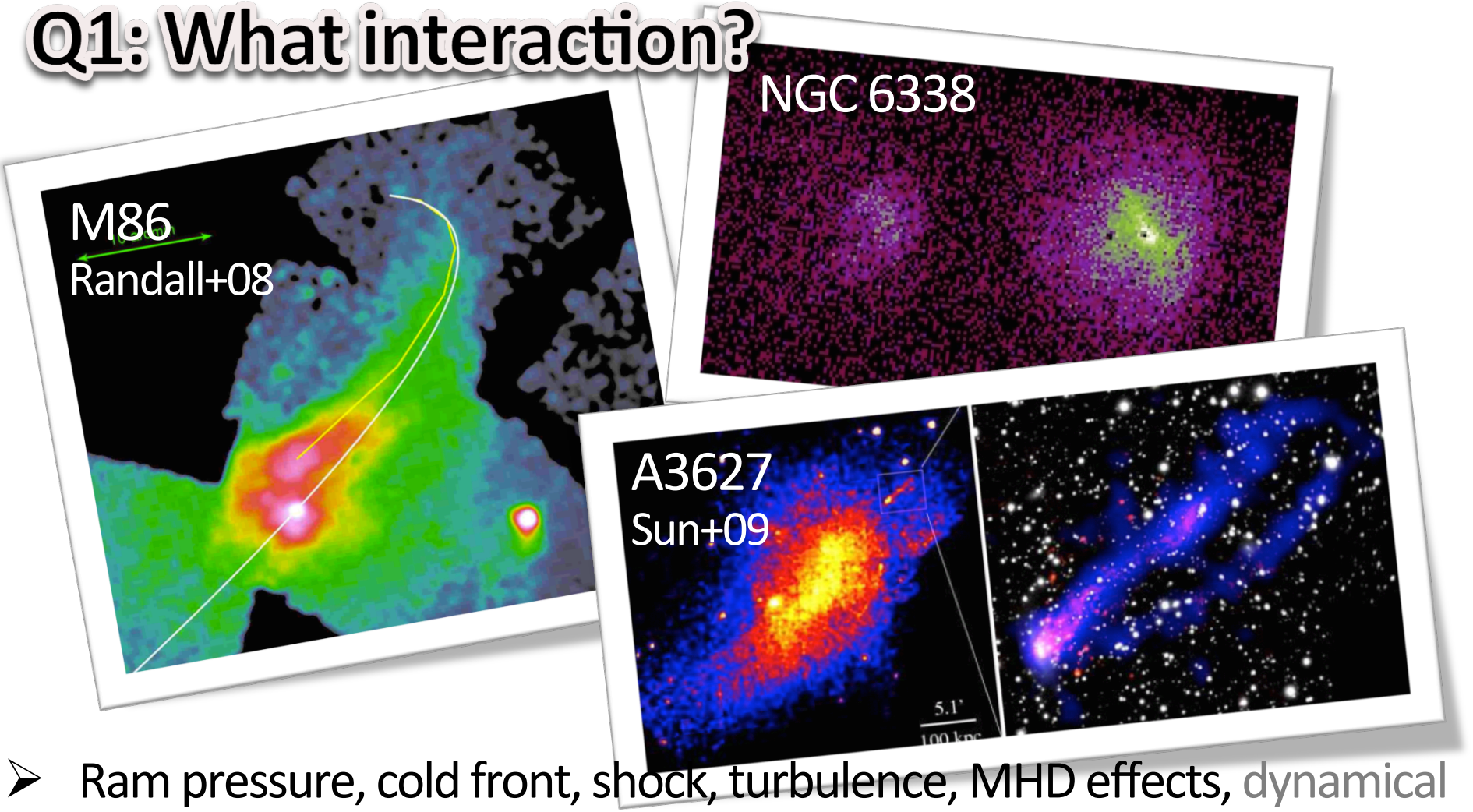
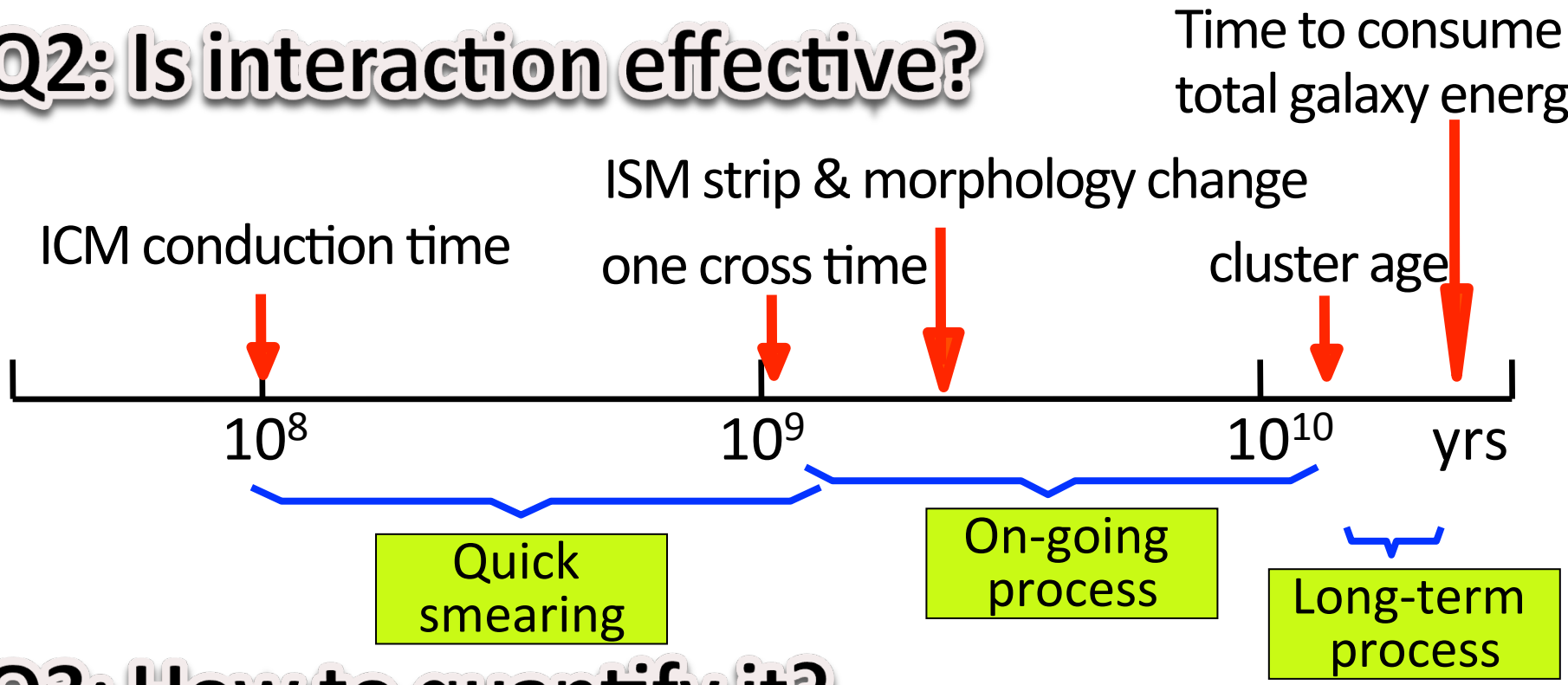
Q1: What interaction?



- Ram pressure, cold front, shock, turbulence, MHD effects, dynamical friction…
- Free energy transfered from galaxy to ICM
- Galaxy more and more concentrated than the ICM

Q2: Is interaction effective?



Q3: How to quantify it?

More individual case study? Galaxy environmental effect? ICM heating/ turbulence probe? Metal mass-to-light ratio?

Why not do more directly

Galaxy light distribution vs. ICM distribution for different-z

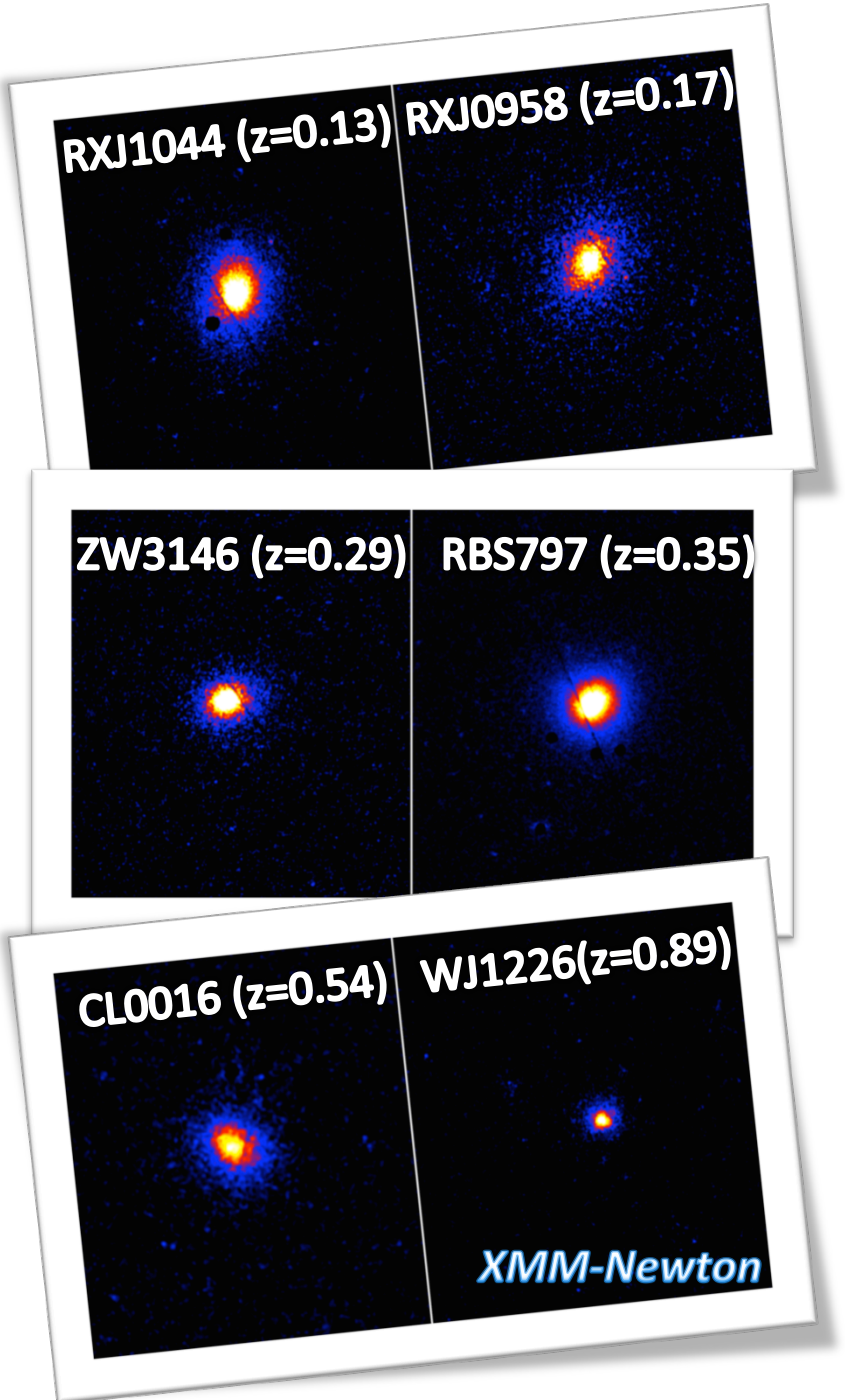
Cluster sample

We study a sample of **34** clusters, with redshift range of **0.1-0.9**.
The sample is selected via

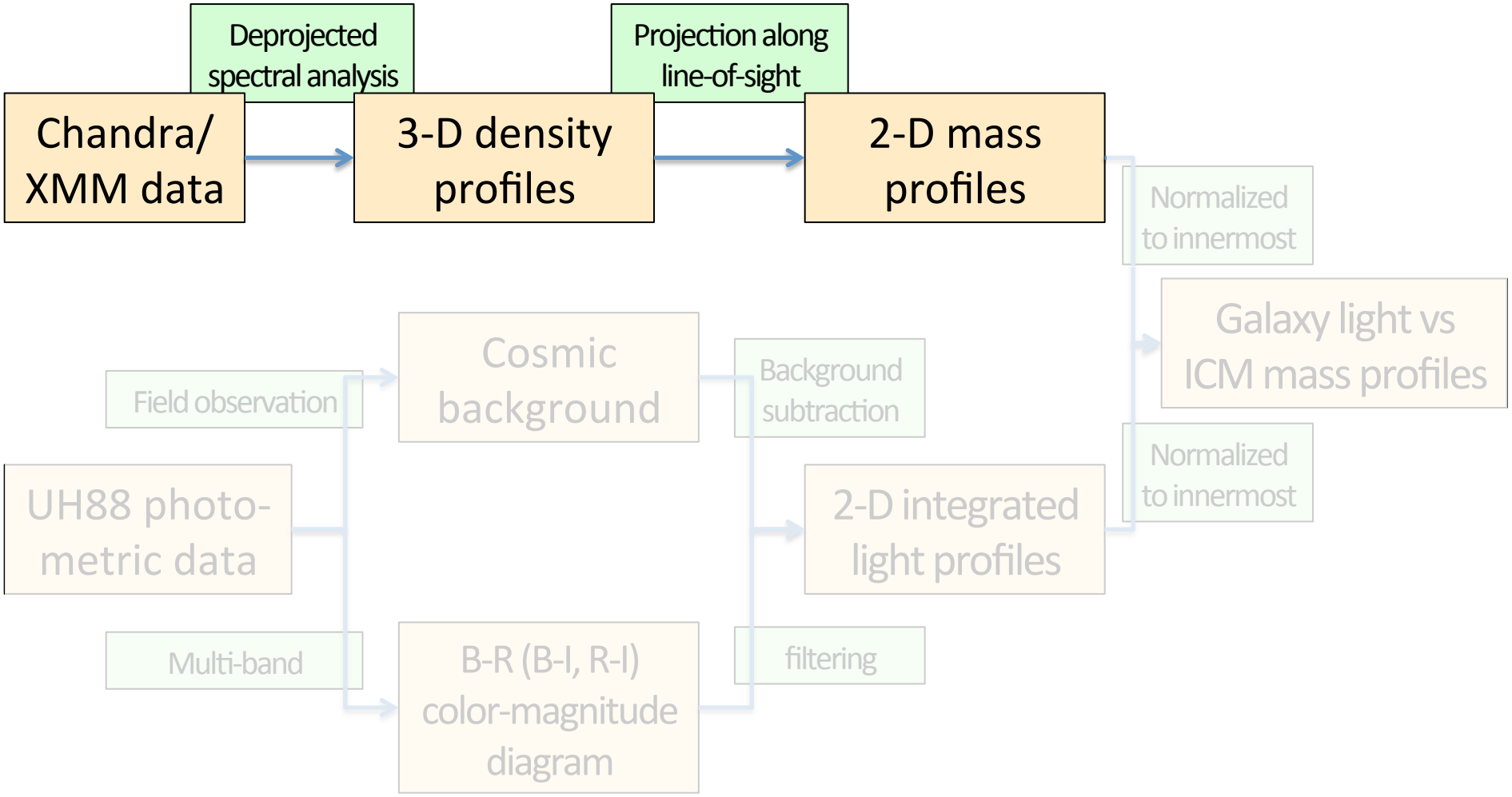
- Similar average ICM temperature (5±2 keV)
- Relaxed X-ray morphology
- Apparent central dominate galaxy
- Offset between X-ray/optical peak < 0.02 R_{500}

Datasets

- UH88 I-band image (PI: Dr. Inada)
- *XMM-Newton* for z<0.5
- *Chandra* (if available) for z>0.5

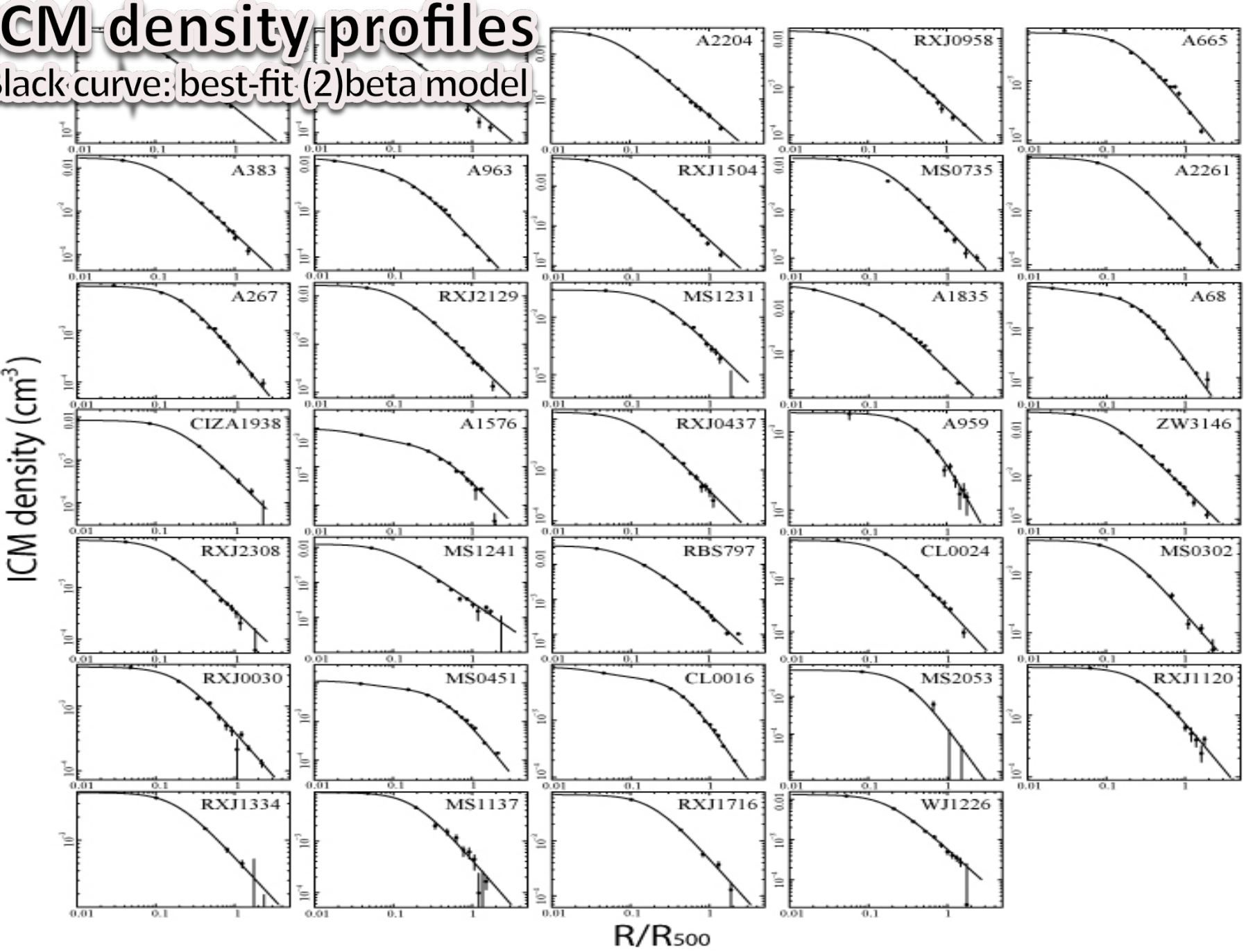


ICM mass profiles

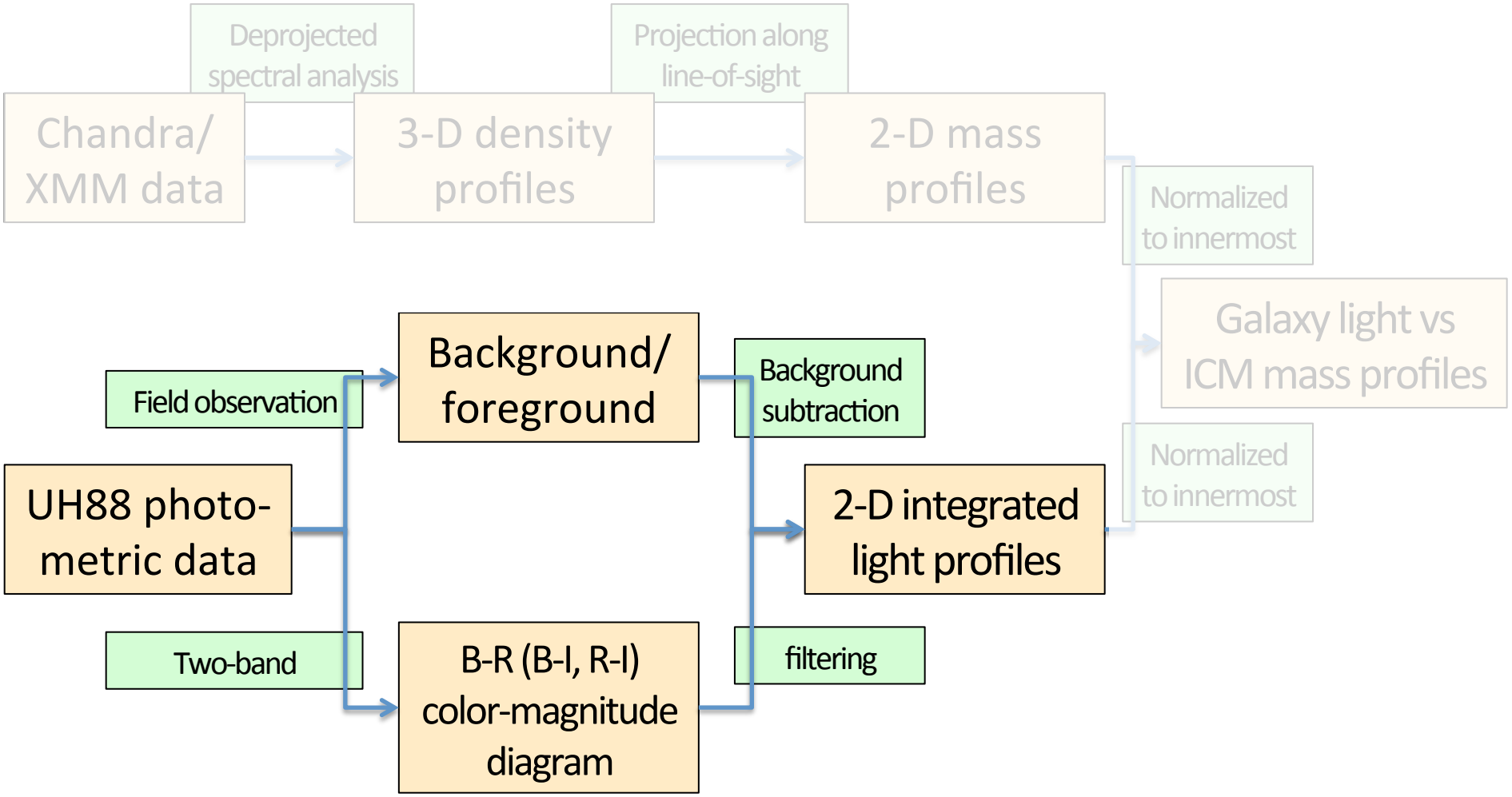


ICM density profiles

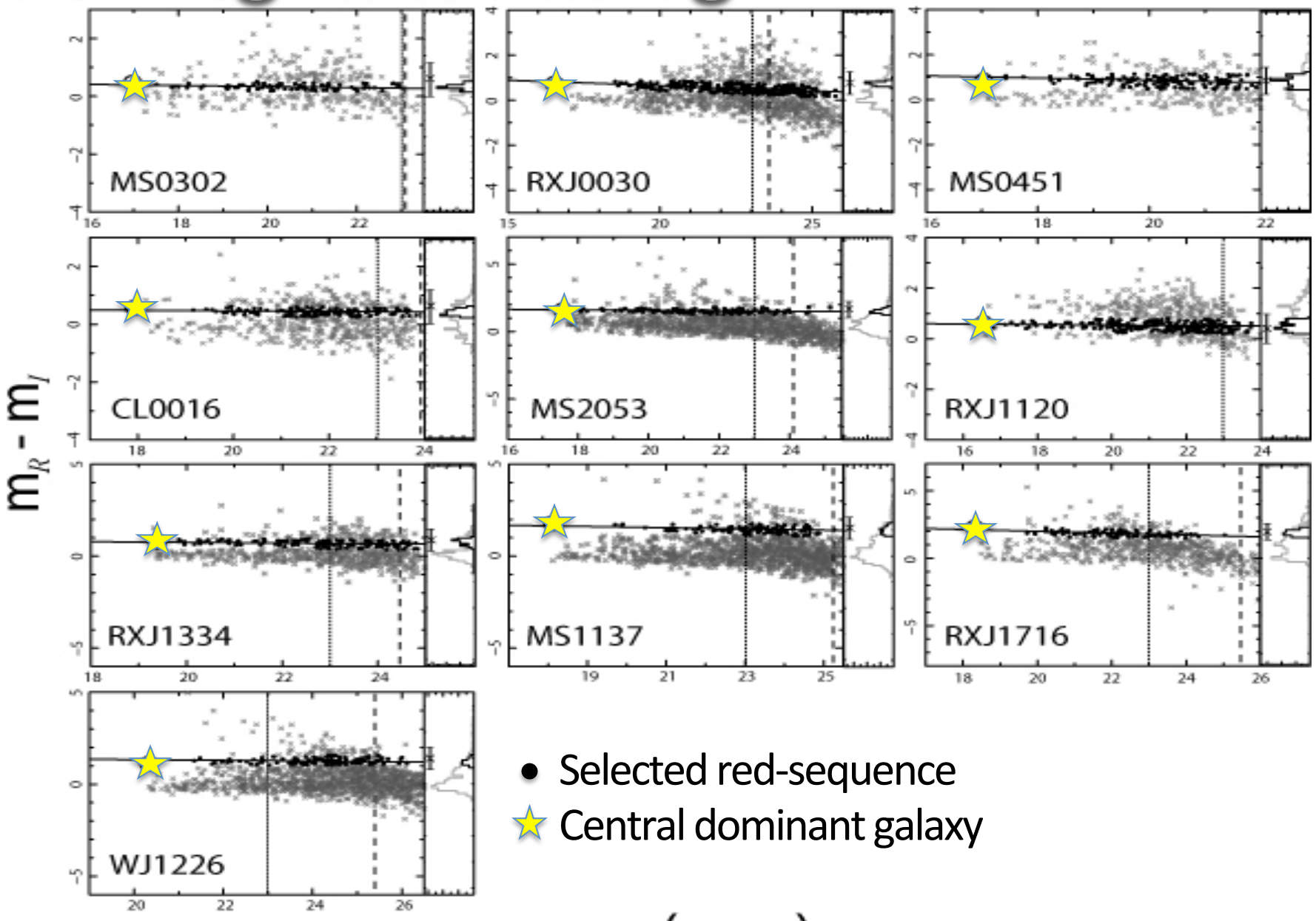
Black curve: best-fit (2)beta model



Galaxy light profile

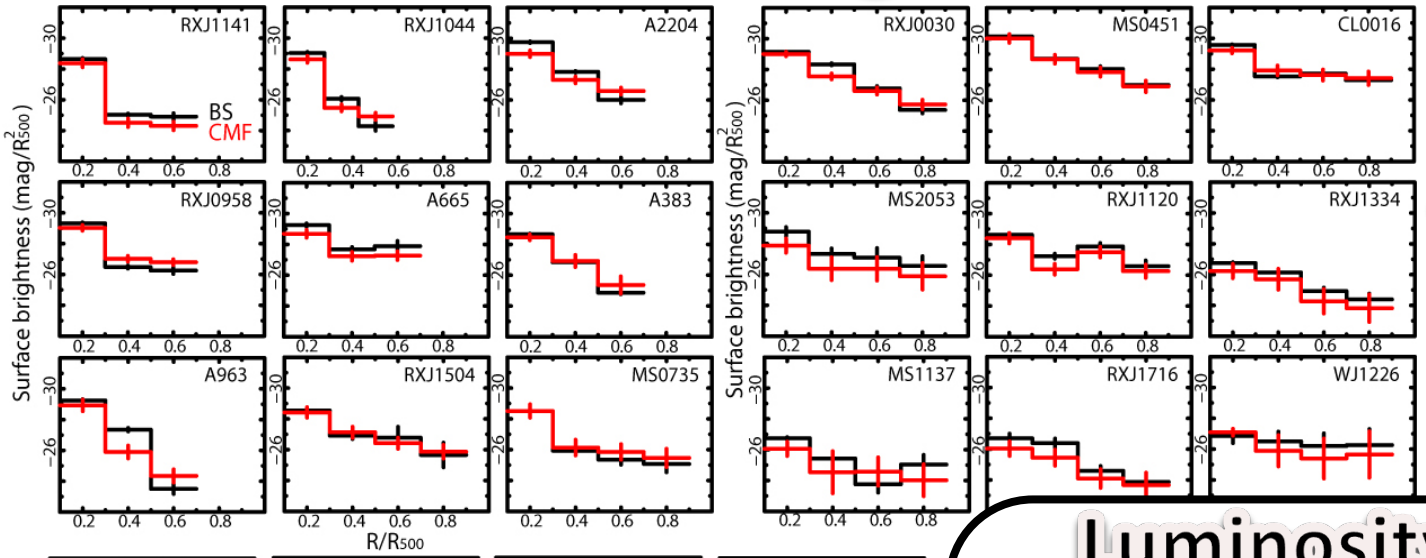


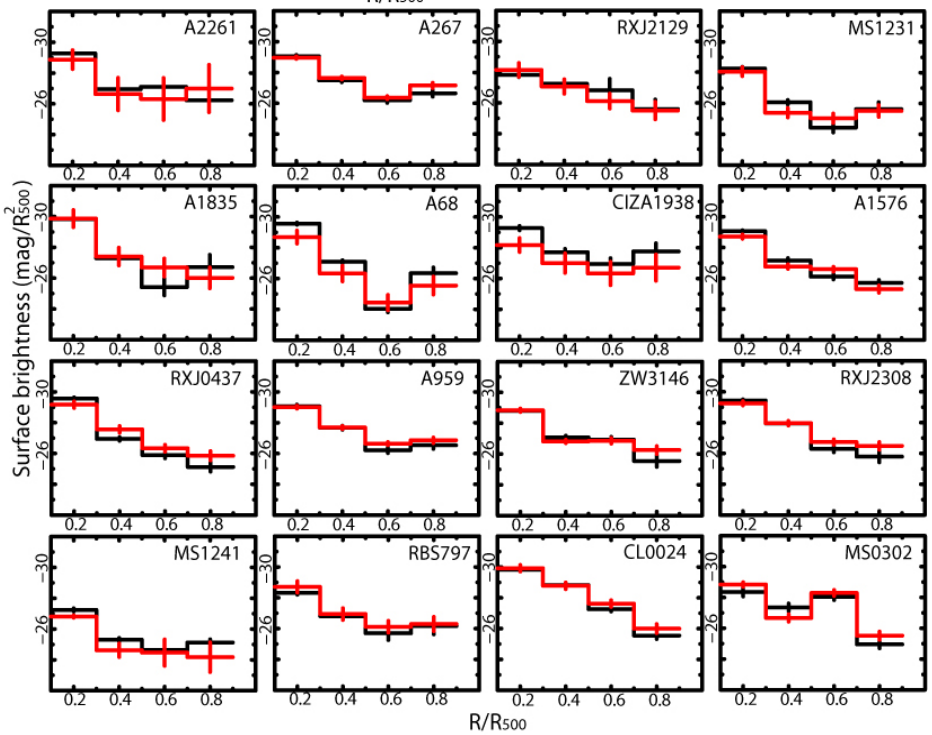
Color-Magnitude Filtering



- Selected red-sequence
- ★ Central dominant galaxy

I-band surface brightness

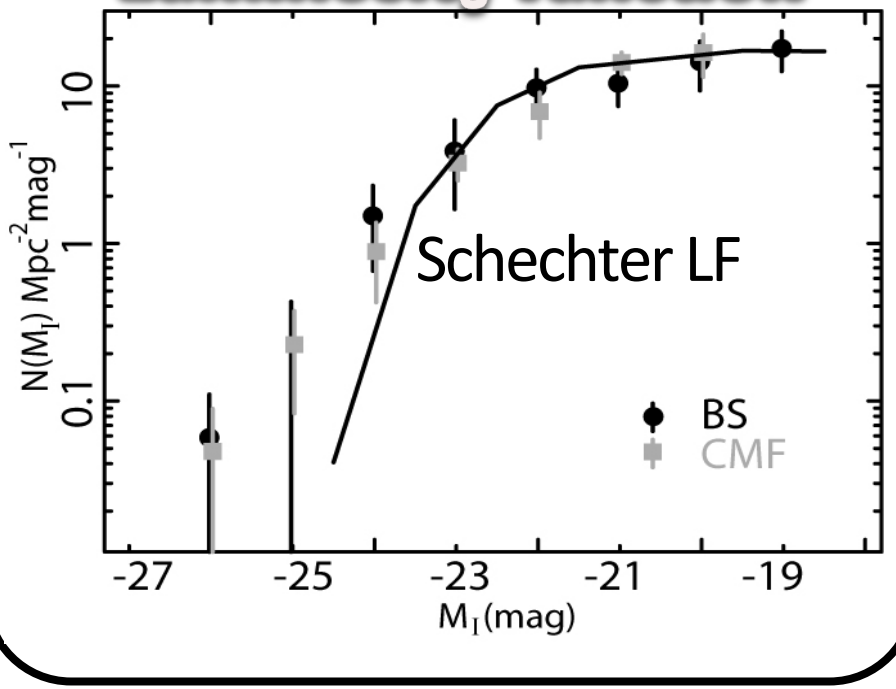




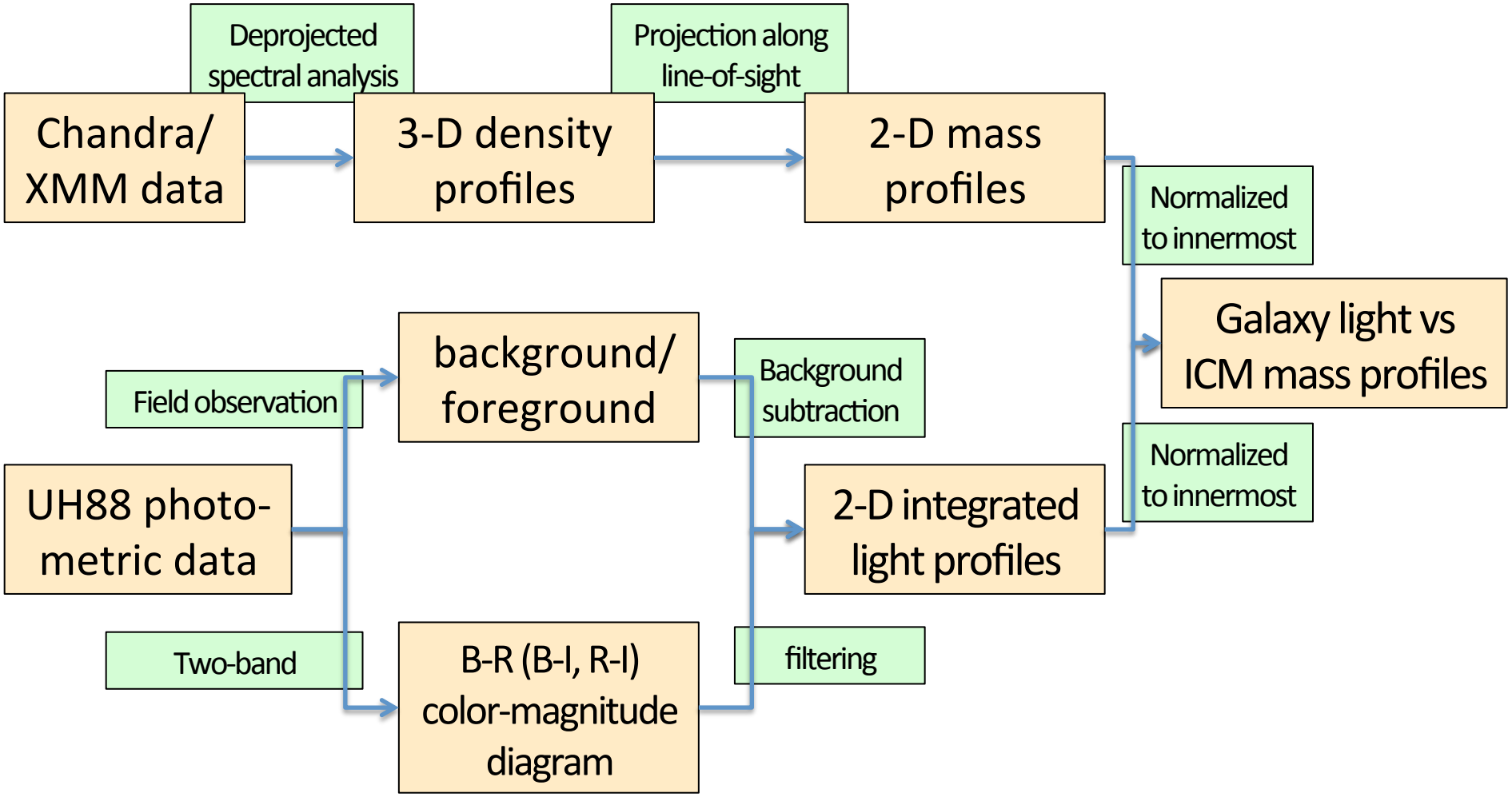
Red: color-magnitude filtered

Black: background subtracted

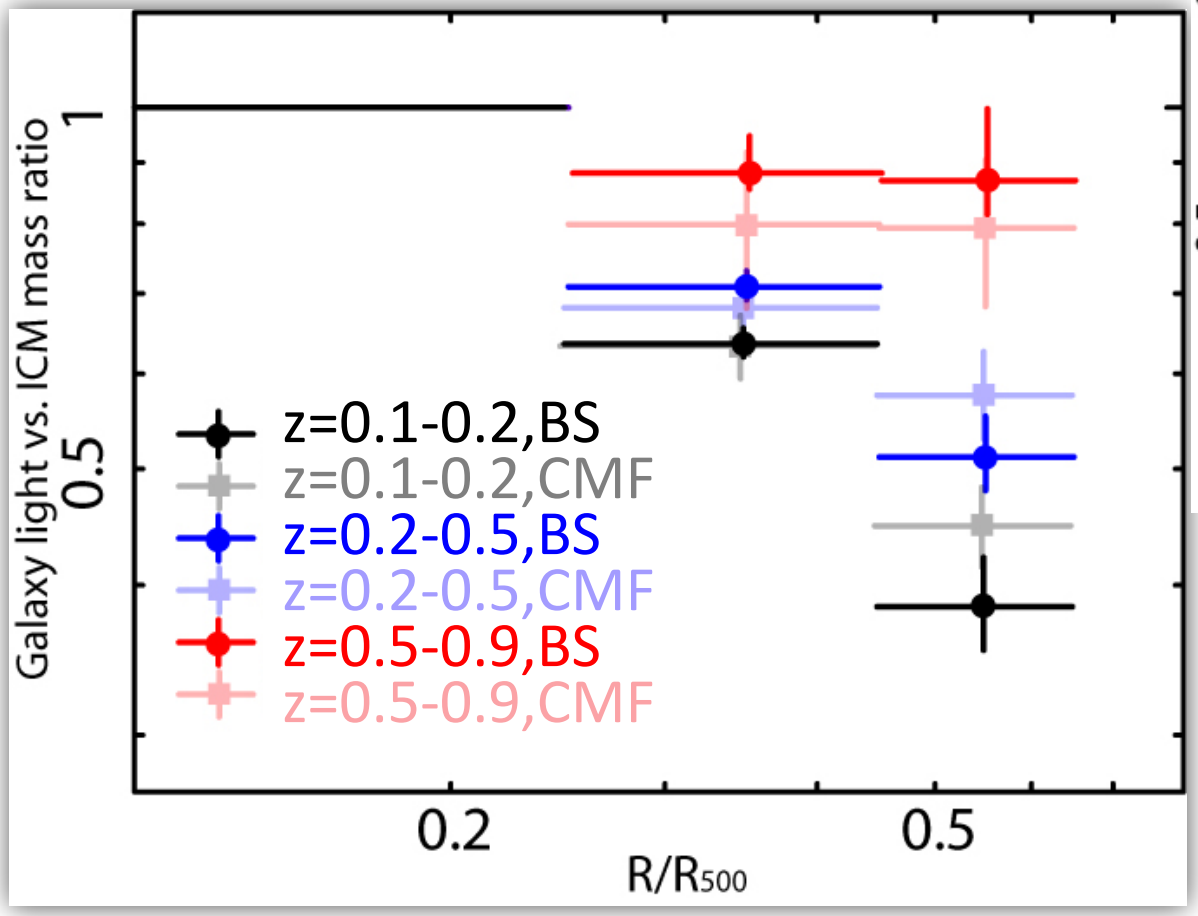
Luminosity function



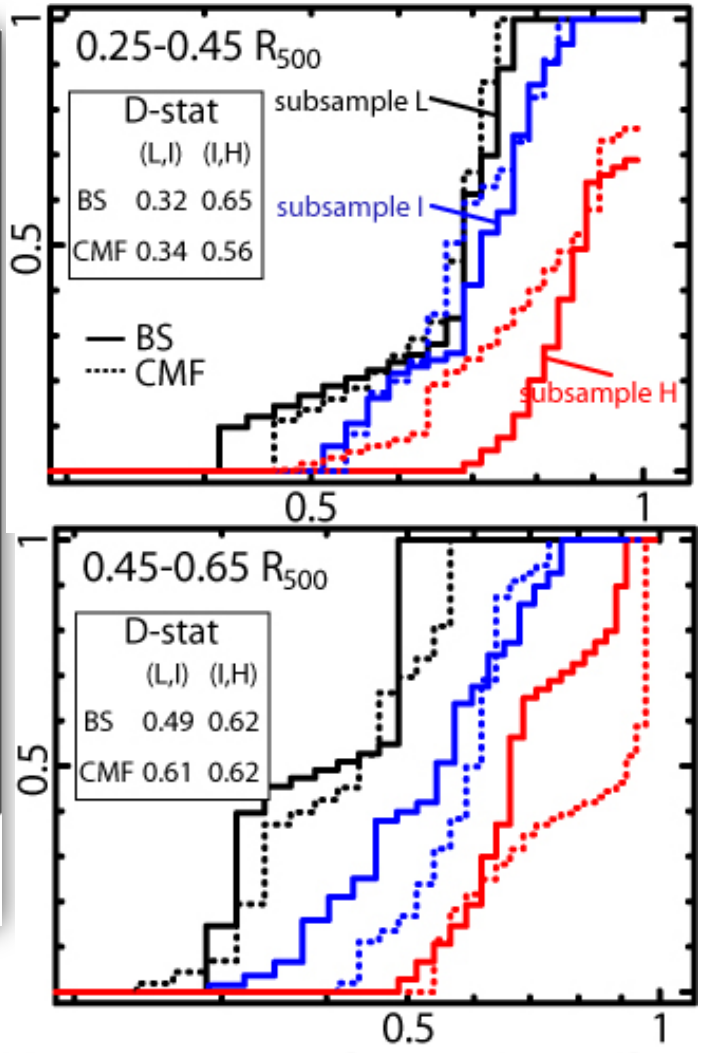
Galaxy light vs ICM mass profile



Galaxy light vs. ICM mass ratio profiles

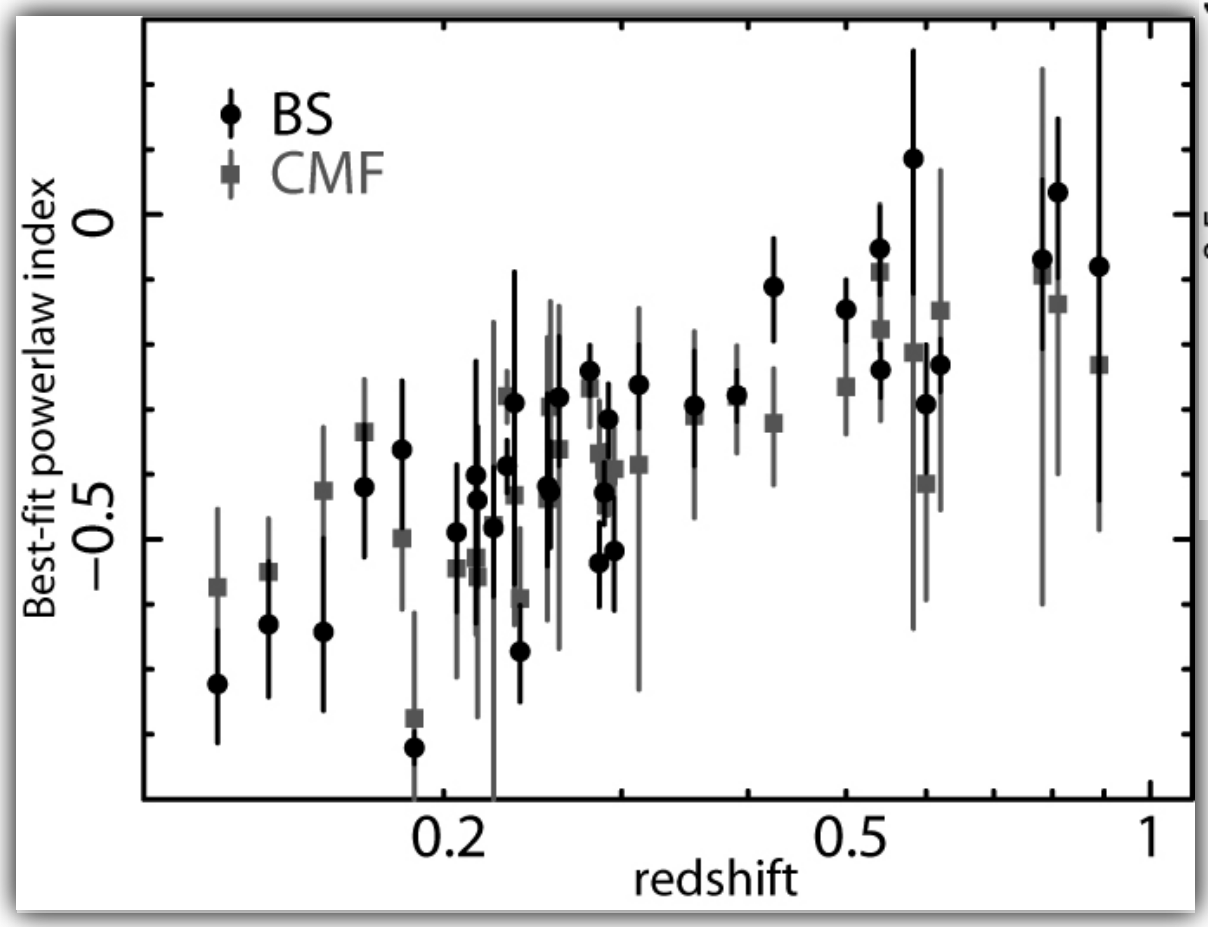


K-S cumulative distribution

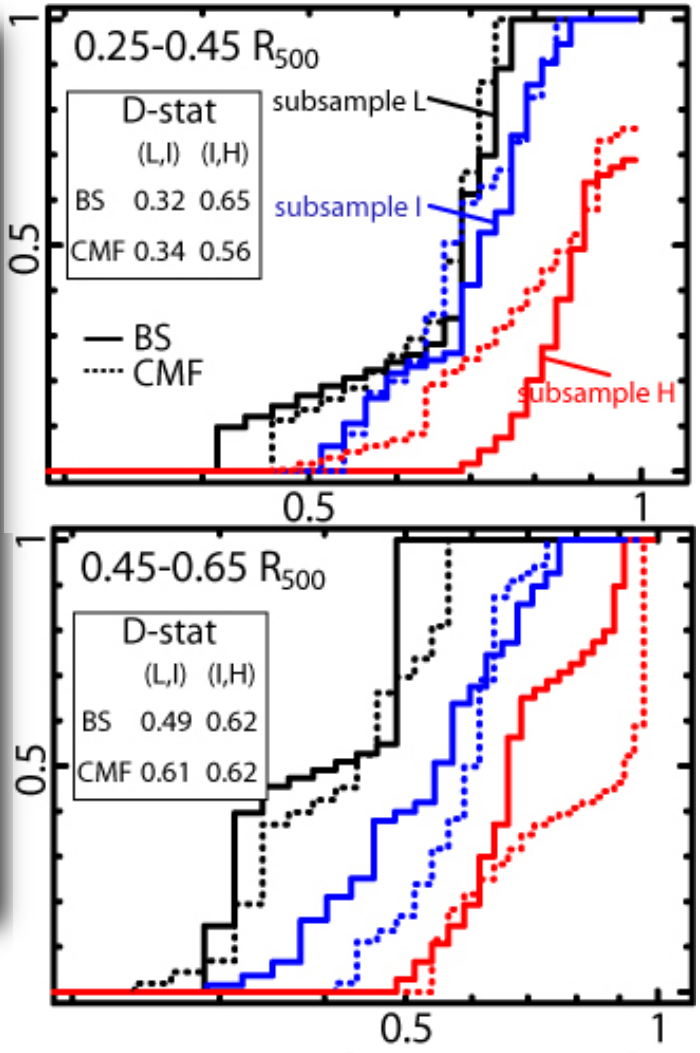


Stellar-to-ICM ratio concentrated by half @ $0.5R_{500}$ (95% level)

Galaxy light vs. ICM mass ratio profiles



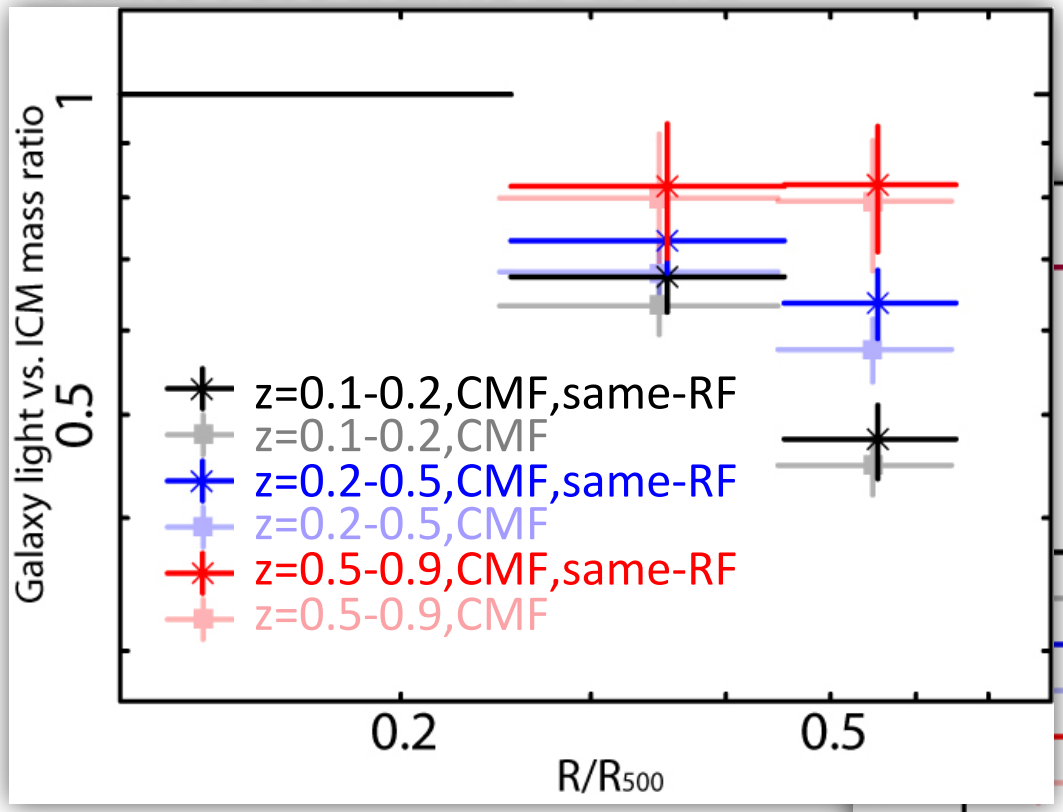
K-S cumulative distribution



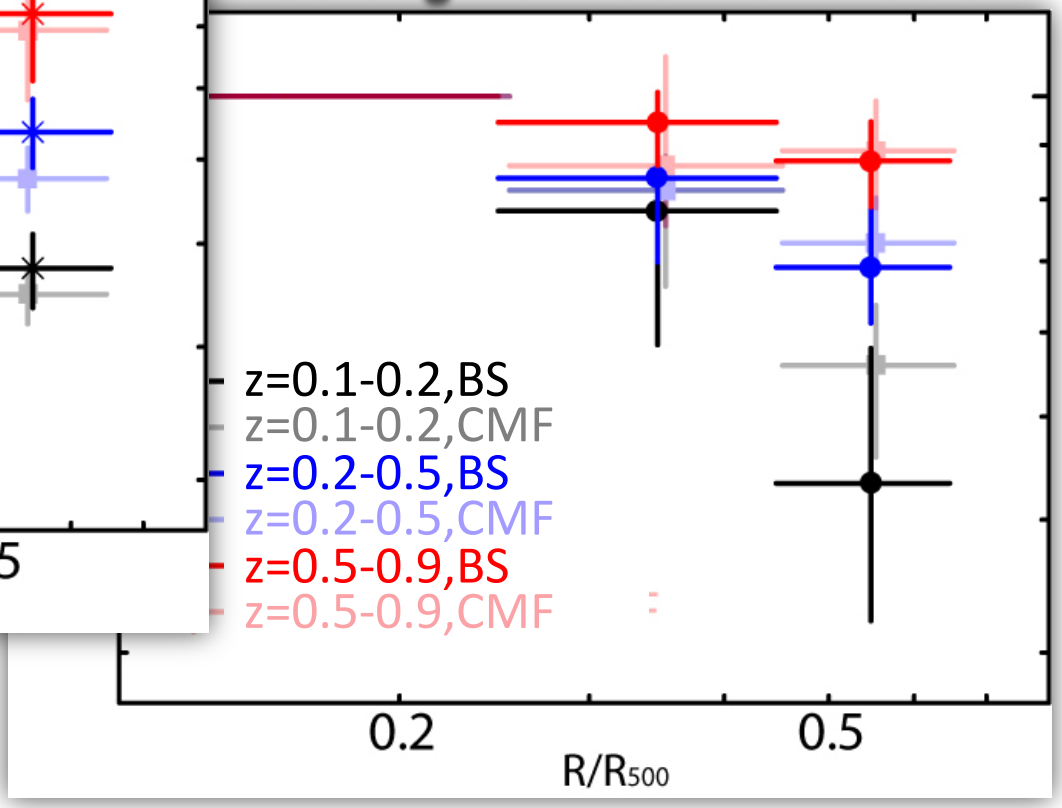
Stellar-to-ICM ratio concentrated by half @ $0.5R_{500}$ (95% level)

Testing bias factors

Same rest-frame B-band

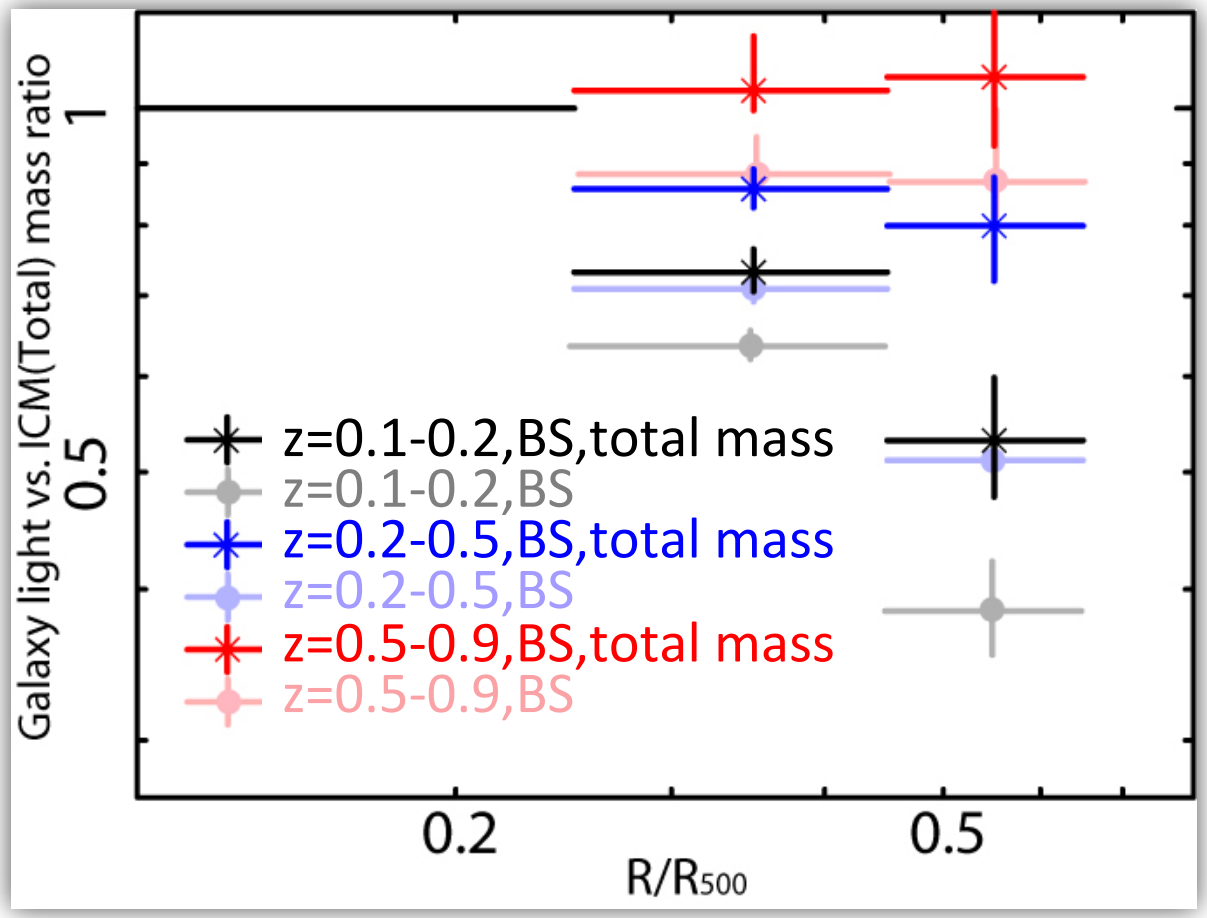


Galaxy number-ICM ratio



- ✗ Cluster color gradient
- ✗ Over-luminous BCG
- ✗ Variation of galaxy luminosity by e.g., star formation

Galaxy light vs. total mass ratio profile



- Galaxy/ICM/DM follow similar distribution at high-z
- Concentration: galaxy<DM<ICM

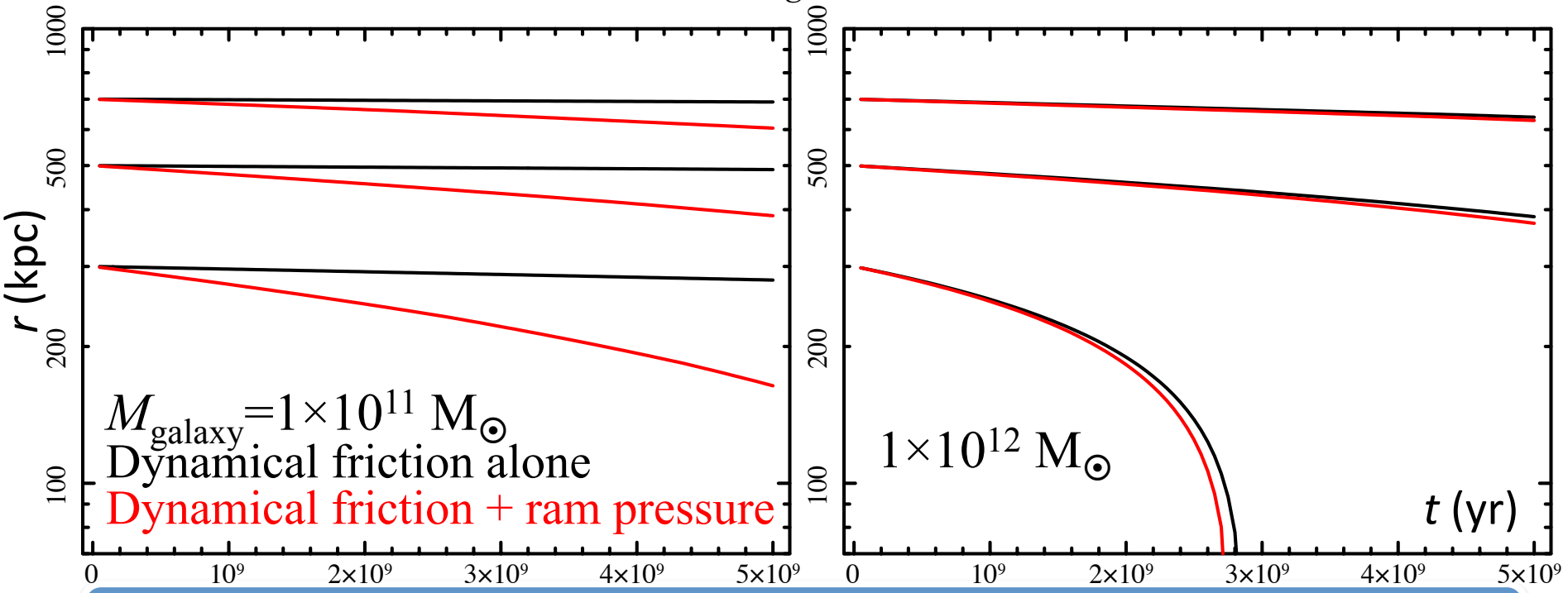
Dynamical friction vs. ram pressure

Dynamical friction

$$F_{DF} = -4\pi\rho_{total}(GM_{galaxy})^2 \ln\Lambda \, [\mathrm{erf}(X)-(2X/\sqrt{\pi})\exp(-X^2)] \, /v^2$$

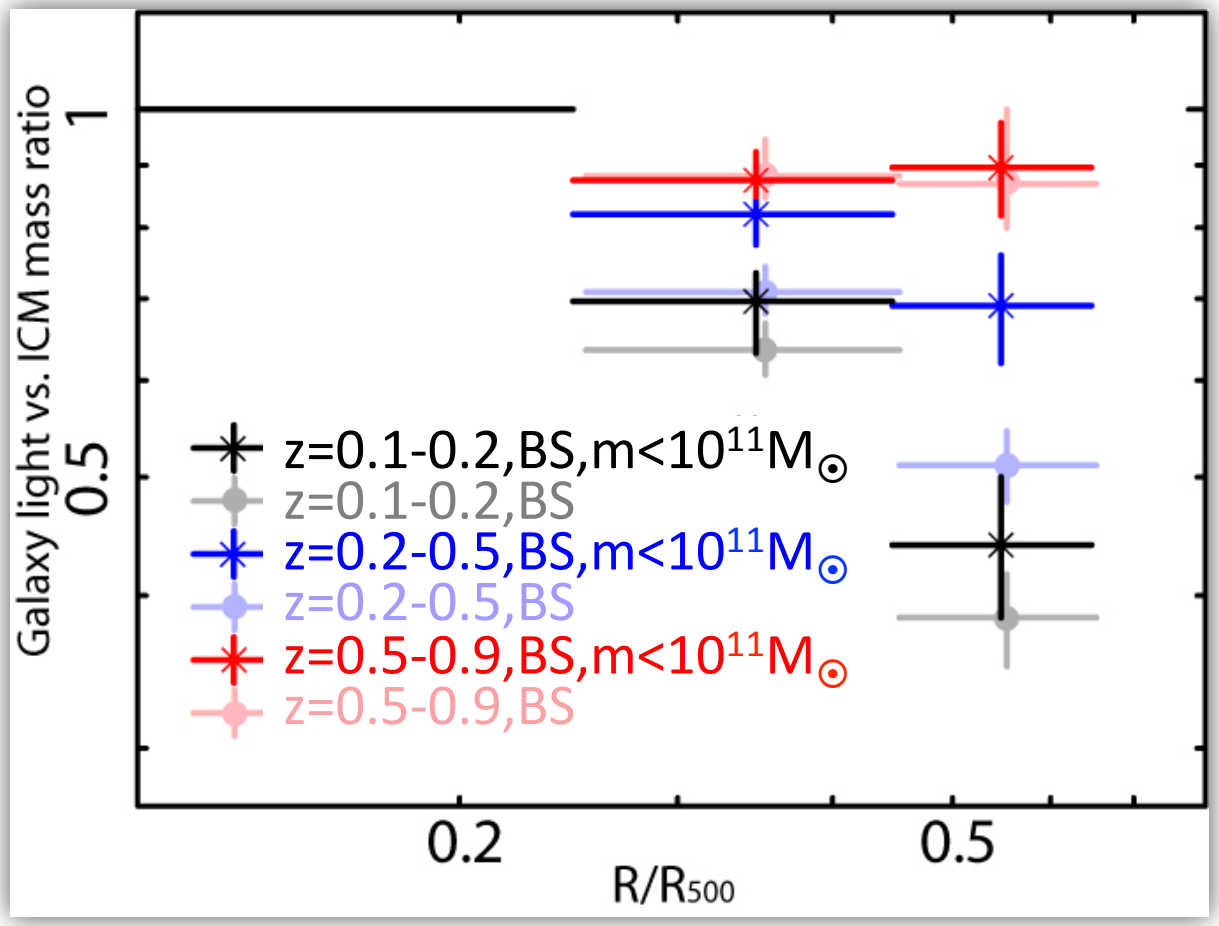
Ram pressure

$$F_{RP} = \pi R_{Int}^2 \rho_g v^2, \;\; R_{Int} \sim R_D$$



Dynamical friction only effective for most massive galaxies

Low-mass galaxy light vs. ICM mass ratio



Dynamical friction alone insufficient to explain the evolution

Summary

- **Stellar component concentrated faster than the ICM from z=0.9-0.1; galaxy light-to-ICM mass ratios drop by ~2 within 0.5 R_{500}**
- **The evolution is robust against various redshift-dependent biases**
- **This result provides important supports for galaxy-ICM interaction**