Using Member Galaxy Luminosities As Halo Mass Proxies

Submitted to ApJ

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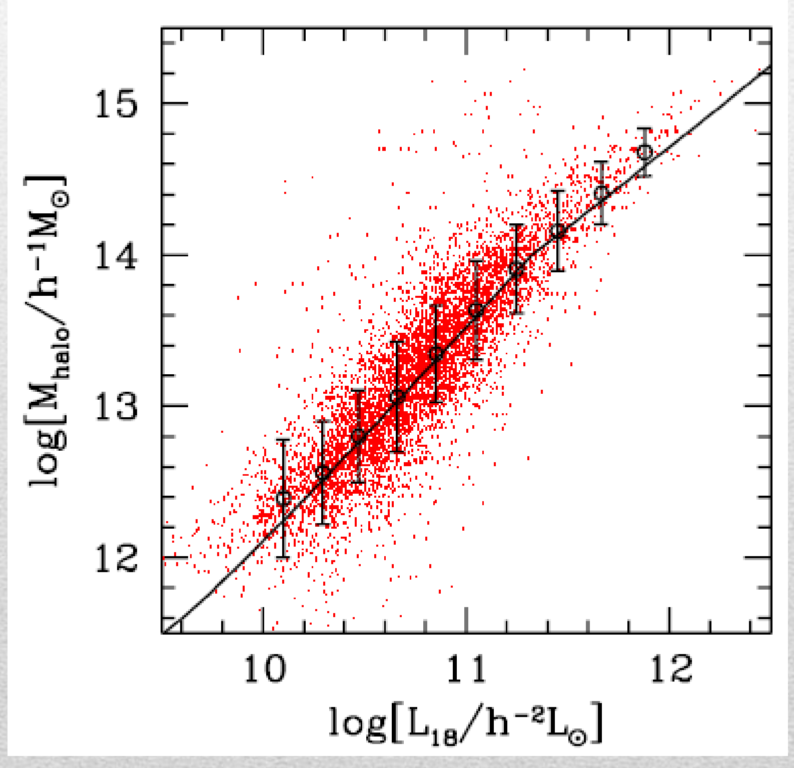
Halo Mass Estimation

Mass Tracer :

- Hot Gas
  - X-ray Emission
  - Sunyaev – Zeldovich Effect
- Galaxies
  - Velocity dispersion
  - Richness
  - Total Luminosity
- Weak Lensing

Characteristic Luminosity

Total luminosity of member galaxies above a luminosity threshold



Yang et al. 2005

Have been applied to many galaxy redshift surveys to construct galaxy groups:
2dFGRS (Yang et al. 2005)
SDSS DR4 DR7 (Yang et al. 2007)

Work well for:
1. Moderately deep redshift survey
2. Large survey

Have difficulty for:
1. Shallow or High redshift server
2. Survey volume is irregular

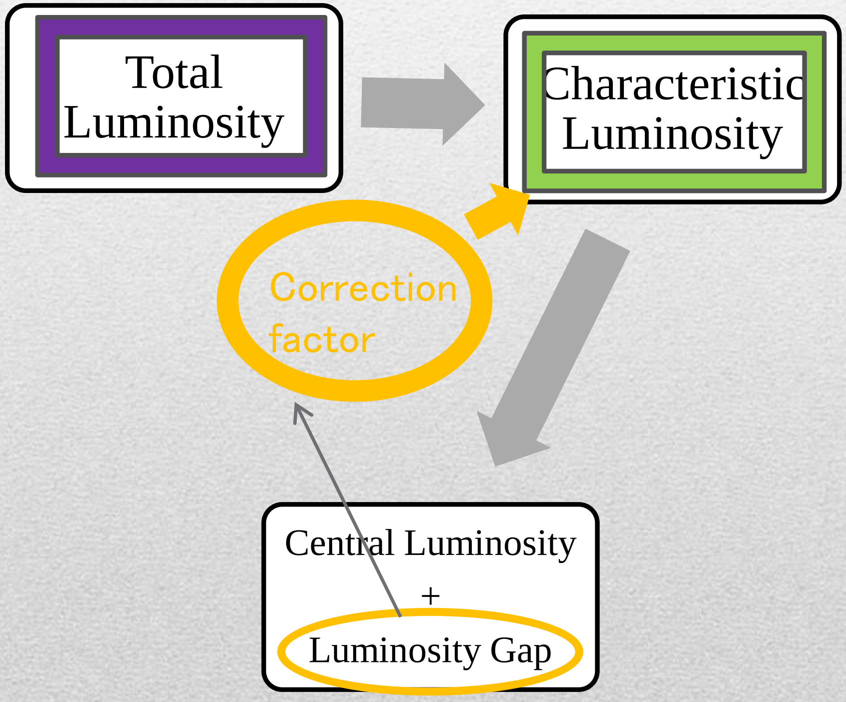
Purpose & Method :

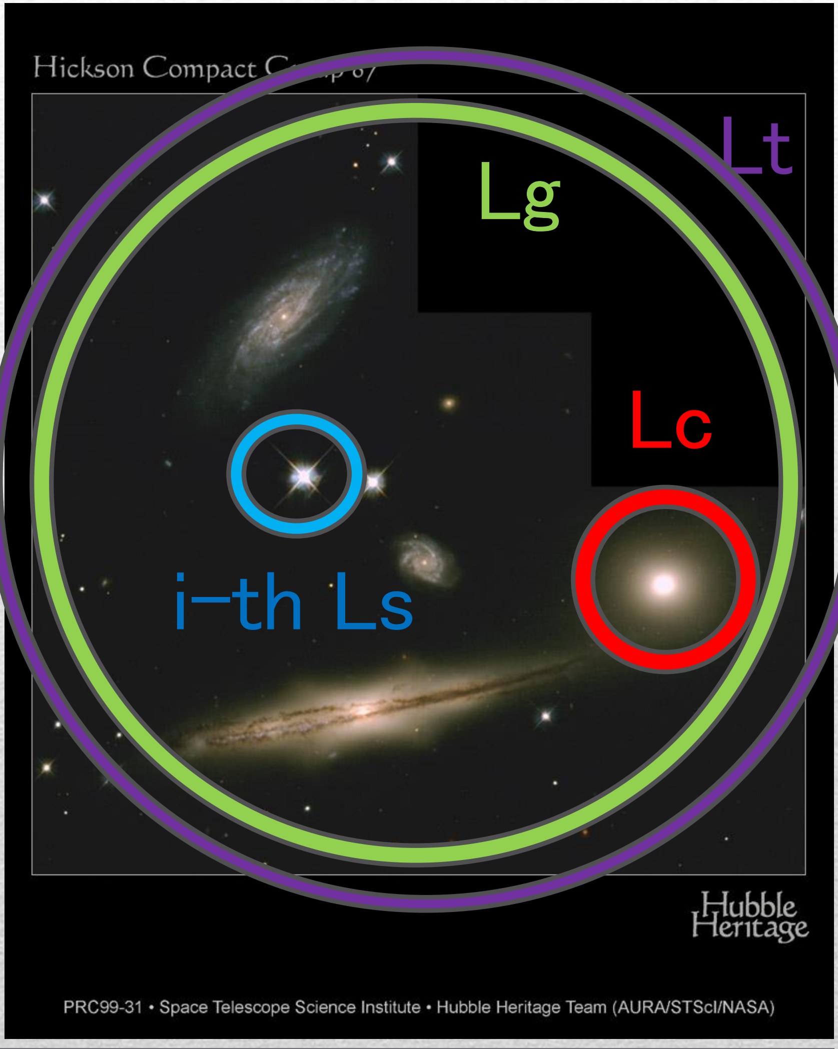
Purpose: provide an alternative halo mass estimation

Method:

$$L_{\rm gap} = L_c / L_s$$

$$\log L_{\rm gap} = \log L_c - \log \bar{L}_s$$





Outlines :

- Sample
- Relations between Halo mass (Mh) and Central Luminosity (Lc)
- Relations between Halo mass (Mh) and Luminosity Gap (Lg)
- “GAP” halo mass estimator
- The performance of our new halo mass estimation

Sample :

- CLF (CLF1 & CLF2)

  Yang et al. 2004: populating dark matter halos obtained from numerical simulations with galaxies of different luminosities according to the conditional luminosity function (CLF). Halo catalogue from the ‘Millennium Run’ I and III respectively.

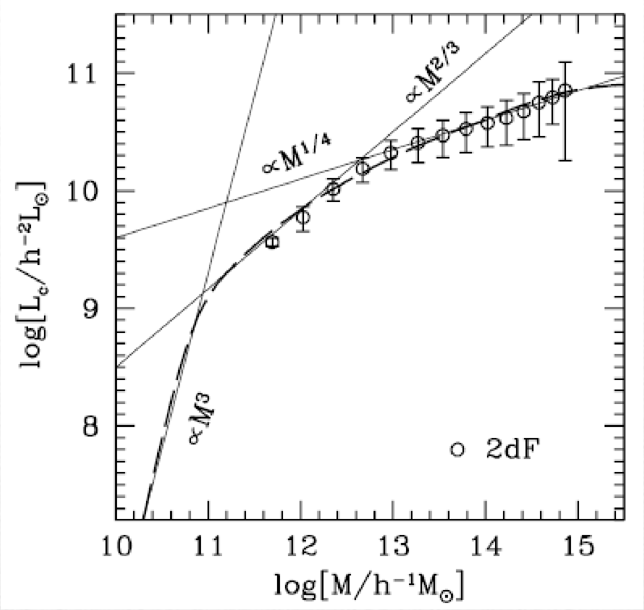
- SAM

  Guo et al. 2011: semi-analytic model of galaxy formation applied to dark matter halo merging trees obtained from ‘Millennium Run’ N-body simulation.

- SHAM

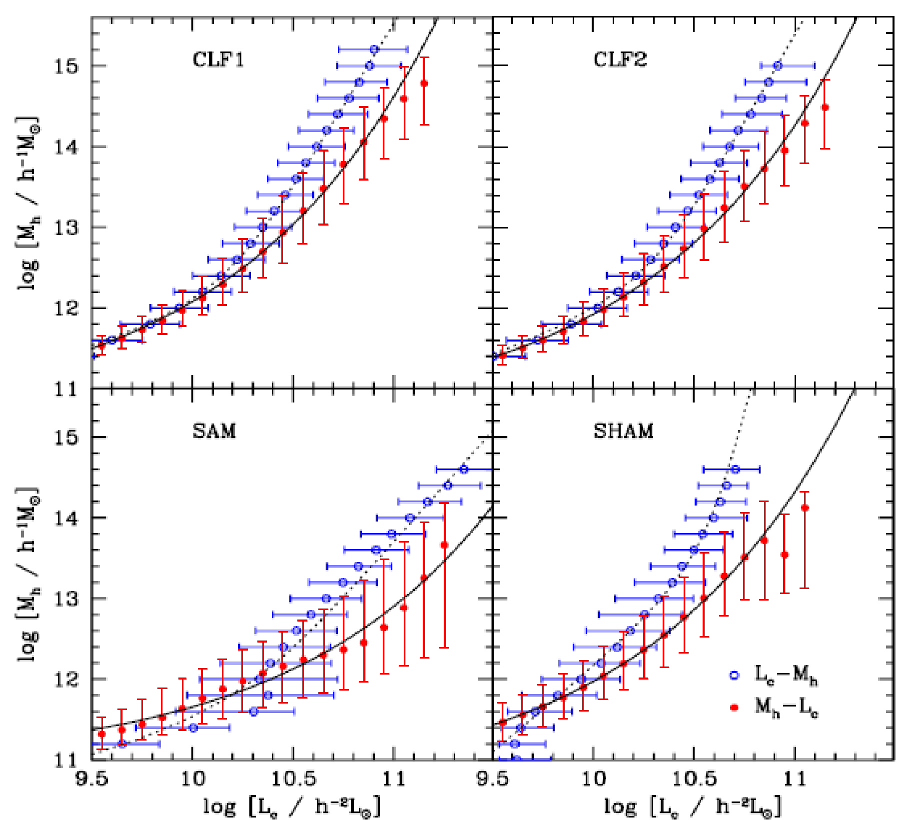
  Hearin et al. 2013: based on Bolshoi N-body simulation involving ROCKSTAR halo finder, using subhalo abundance matching (SHAM) technique to associate galaxies with dark matter halos and subhalos.

Central Luminosity



Yang et al. 2005

$$L_c(M_h) = L_0 \frac{(M_h/M_1)^{\gamma_1}}{(1+M_h/M_1)^{\gamma_1-\gamma_2}}$$



$$\log M_h = \exp(\log L_c - \log M_a) + \log M_b$$

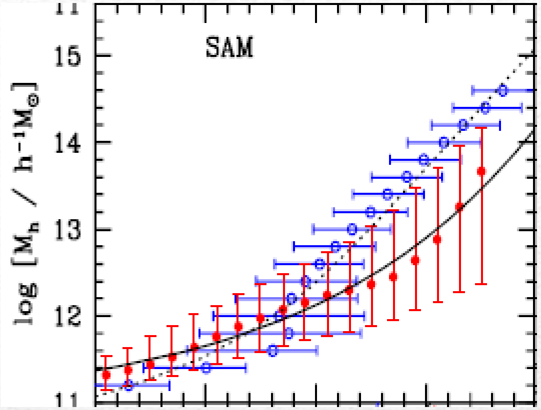
Central galaxy luminosity alone can not provide reliable estimate of halo mass.

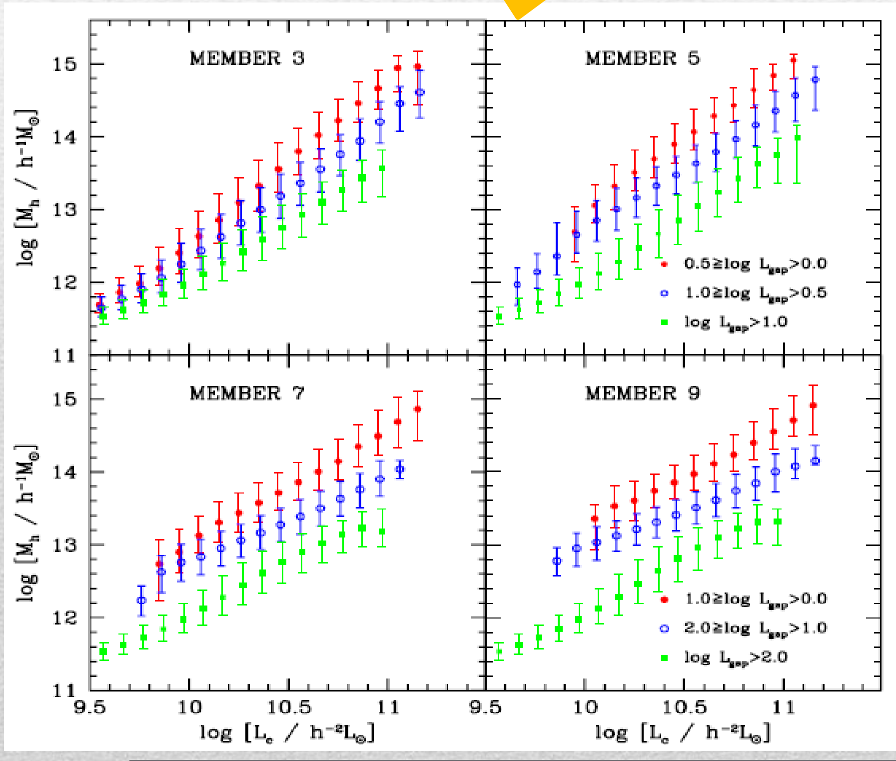
So we use luminosity gap as another parameter to describe halo mass:

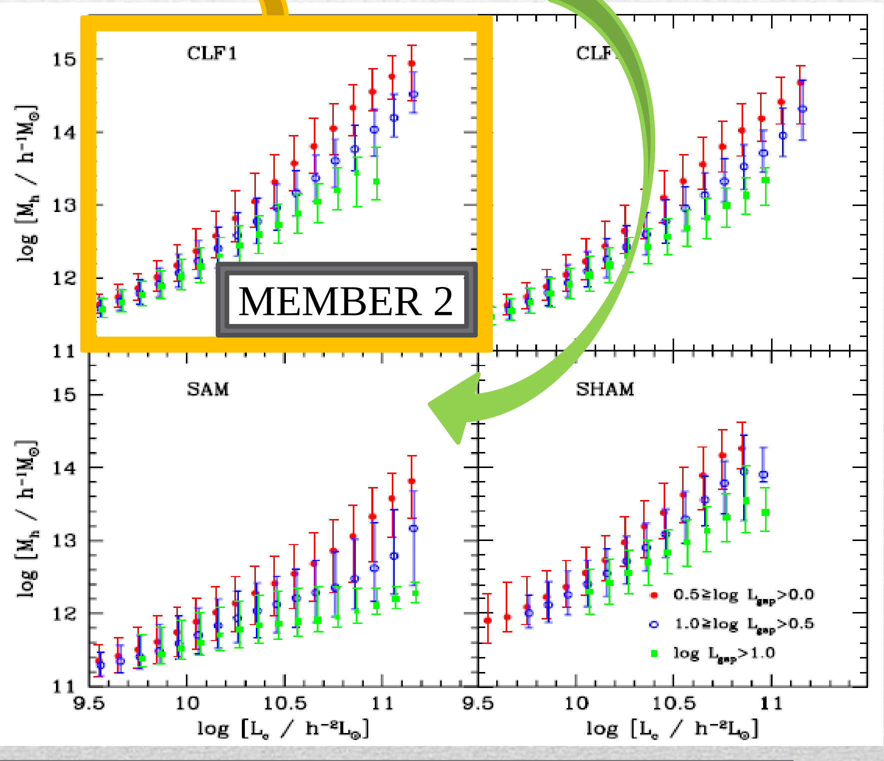
Gap-dependence Relation :

$$\log L_{\rm gap} = \log L_c - \log \bar{L}_s$$

MEMBER 3 : Ls = L3
MEMBER 5: Ls = L5
………….



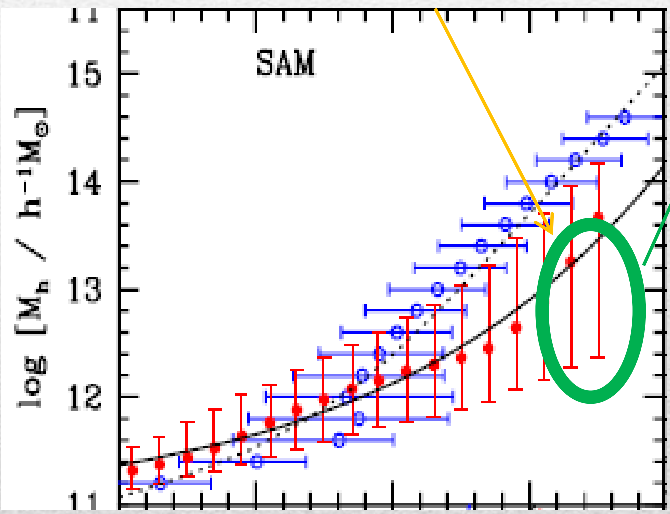




Correction Factor :

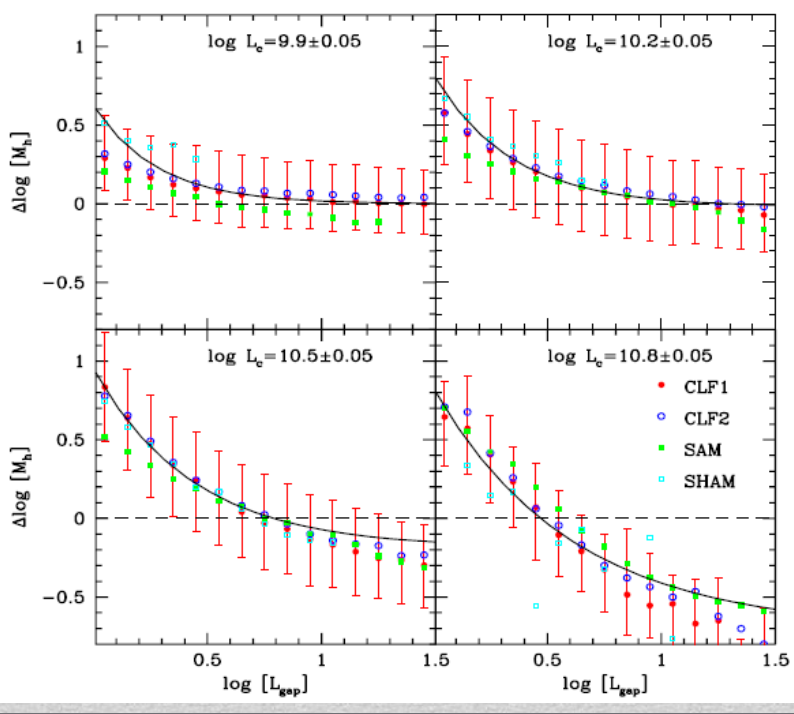
$$\log M_h(L_c, L_{\rm gap}) = \log M_h(L_c) + \Delta \log M_h(L_c, L_{\rm gap})$$

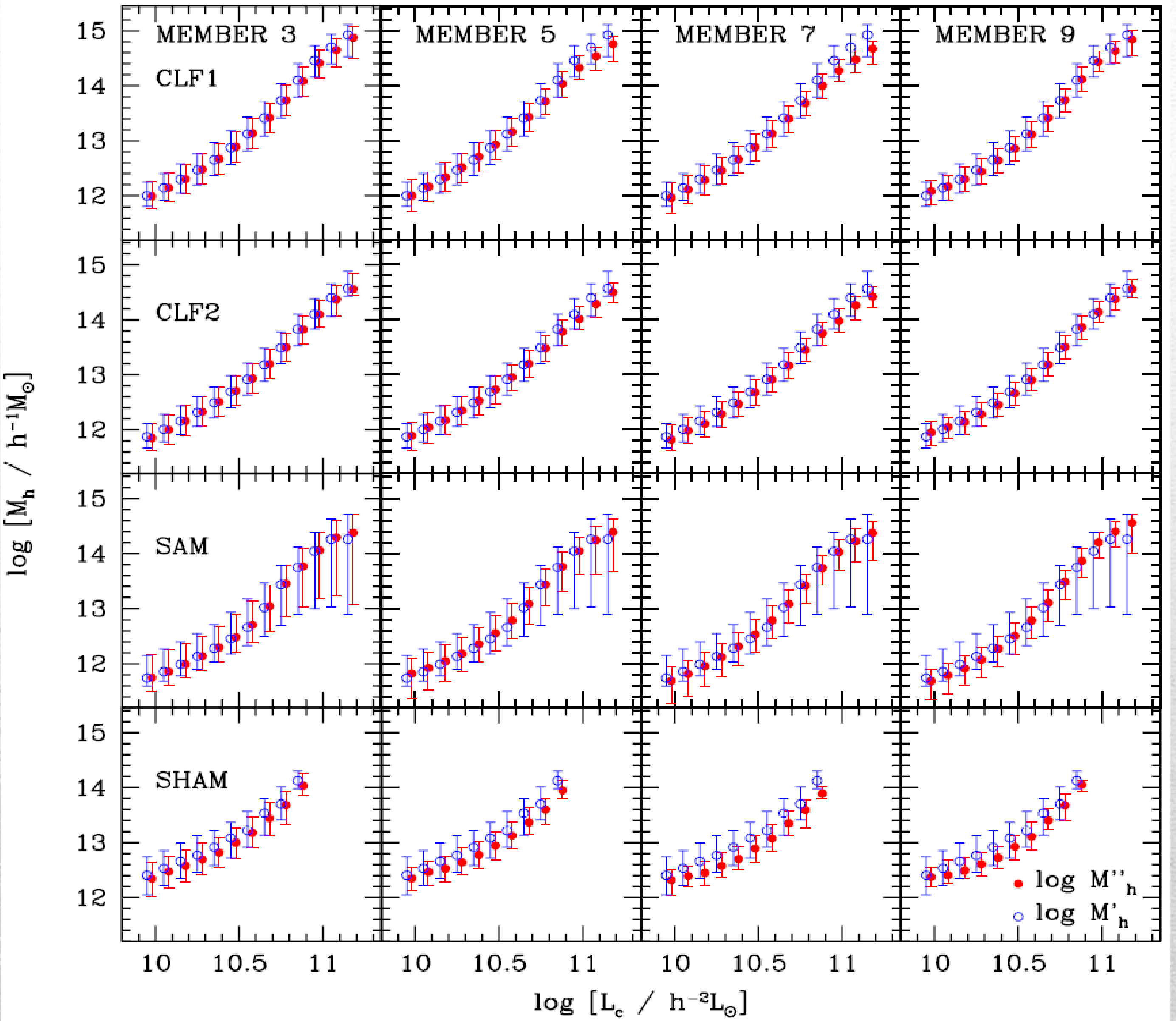
$$\log M_h = \exp(\log L_c - \log M_a) + \log M_b$$



$$\Delta \log M_h(L_c, L_{\rm gap}) = \eta_a \exp(\eta_b \log L_{\rm gap}) + \eta_c$$

$$\eta_a(L_c) = \exp(\log L_c - \alpha)$$
$$\eta_b(L_c) = \beta_2(\log L_c - \gamma_2)\,,$$
$$\eta_c(L_c) = -(\log L_c - \beta_3)^{\gamma_3}$$





MEMBER 3
MEMBER 5
MEMBER 7
MEMBER 9
CLF1
CLF2
SAM
SHAM
log [M_h / h^-1 M_⊙]
log [L_c / h^-2 L_⊙]
log M''_h
log M'_h
10
10.5
11
12
13
14
15

‘GAP’ halo mass estimation :

$$\log M_h(L_c, L_{\rm gap}) = \log M_h(L_c) + \Delta \log M_h(L_c, L_{\rm gap})$$

$$\log M_h = \exp(\log L_c - \log M_a) + \log M_b$$

$$\Delta \log M_h(L_c, L_{\rm gap}) = \eta_a \exp(\eta_b \log L_{\rm gap}) + \eta_c$$

$$\eta_a(L_c) = \exp(\log L_c - \alpha)$$
$$\eta_b(L_c) = \beta_2(\log L_c - \gamma_2)\,,$$
$$\eta_c(L_c) = -(\log L_c - \beta_3)^{\gamma_3}$$

$[\log M_a, \log M_b]$

$[9.61 \pm 0.01, 10.60 \pm 0.01]$

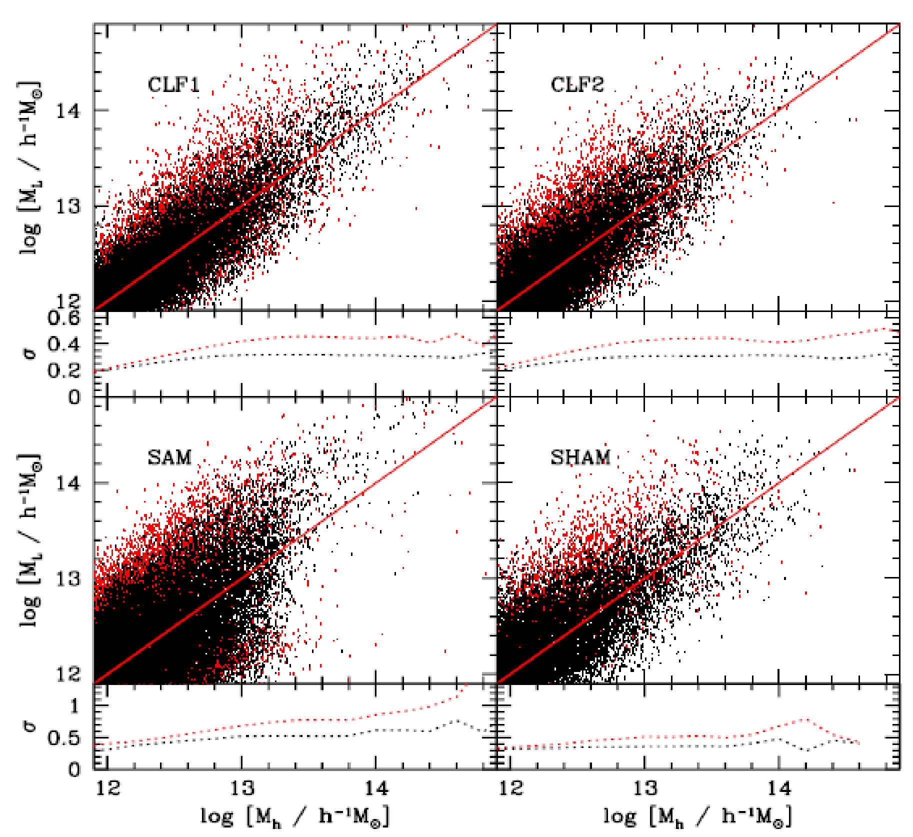
NOTE: All parameters are contributed only by CLF1 model, but can be successfully apply to other samples.

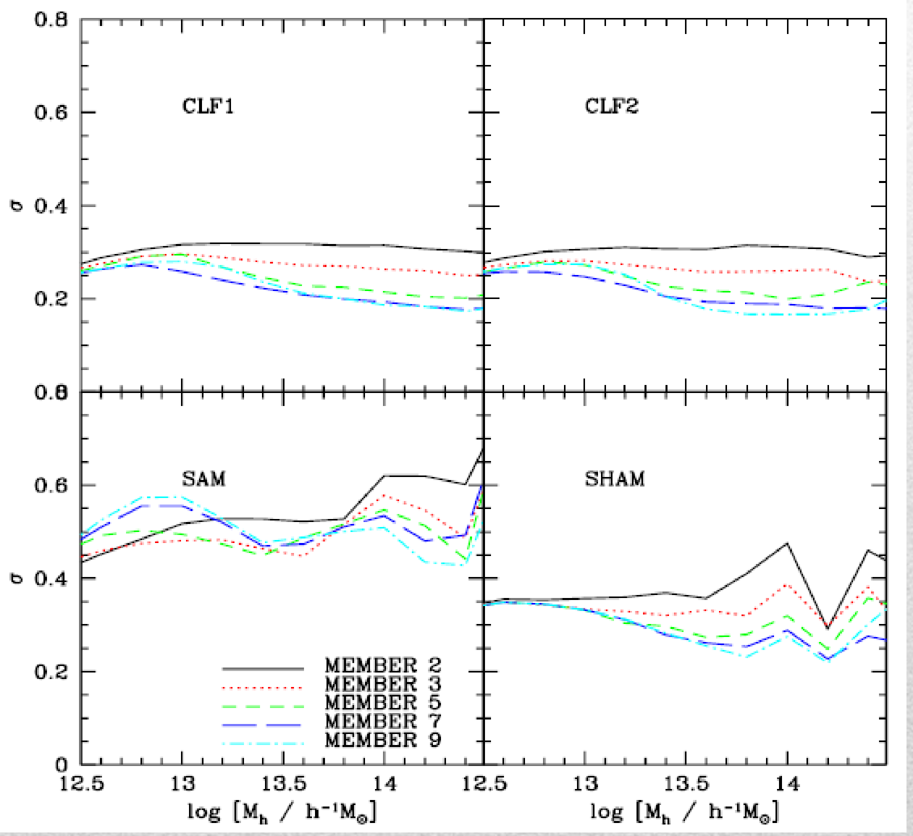
$\Delta \log M_h$	β_1	α_2	β_2	β_3	γ_3
MEMBER 2	$10.37^{+0.23}_{-0.25}$	$2.14^{+4.22}_{-1.81}$	$-11.57^{+0.64}_{-6.40}$	$9.90^{+0.02}_{-0.16}$	$3.29^{+4.13}_{-1.54}$
MEMBER 3	$10.09^{+0.16}_{-0.19}$	$0.25^{+1.50}_{-0.15}$	$-16.51^{+5.29.46}_{-6.62}$	$9.86^{+0.04}_{-0.20}$	$2.92^{+2.00}_{-1.12}$
MEMBER 4	$9.84^{+0.15}_{-0.22}$	$0.15^{+0.71}_{-0.07}$	$-16.70^{+5.18}_{-3.90}$	$9.69^{+0.10}_{-0.21}$	$2.82^{+0.87}_{-0.63}$
MEMBER 5	$9.71^{+0.13}_{-0.18}$	$0.10^{+0.43}_{-0.02}$	$-17.74^{+6.07}_{-0.16}$	$9.60^{+0.10}_{-0.19}$	$2.75^{+0.76}_{-0.35}$
MEMBER 6	$9.57^{+0.11}_{-0.24}$	$0.07^{+0.29}_{-0.01}$	$-18.02^{+6.14}_{-0.39}$	$9.49^{+0.10}_{-0.24}$	$2.77^{+0.40}_{-0.26}$
MEMBER 7	$9.78^{+0.13}_{-0.30}$	$-0.89^{+0.75}_{-0.70}$	$-9.59^{+2.39}_{-0.25}$	$9.80^{+0.10}_{-0.40}$	$2.64^{+1.59}_{-0.74}$
MEMBER 8	$9.53^{+0.33}_{-0.12}$	$-0.28^{+0.13}_{-1.10}$	$-8.84^{+1.00}_{-1.00}$	$9.47^{+0.43}_{-0.16}$	$2.55^{+1.02}_{-0.50}$
MEMBER 9	$9.91^{+0.11}_{-0.20}$	$0.07^{+0.05}_{-0.01}$	$-16.78^{+2.46}_{-0.46}$	$9.38^{+0.07}_{-0.14}$	$2.63^{+0.19}_{-0.18}$

Performances:

- **Compare to True Halo Mass**

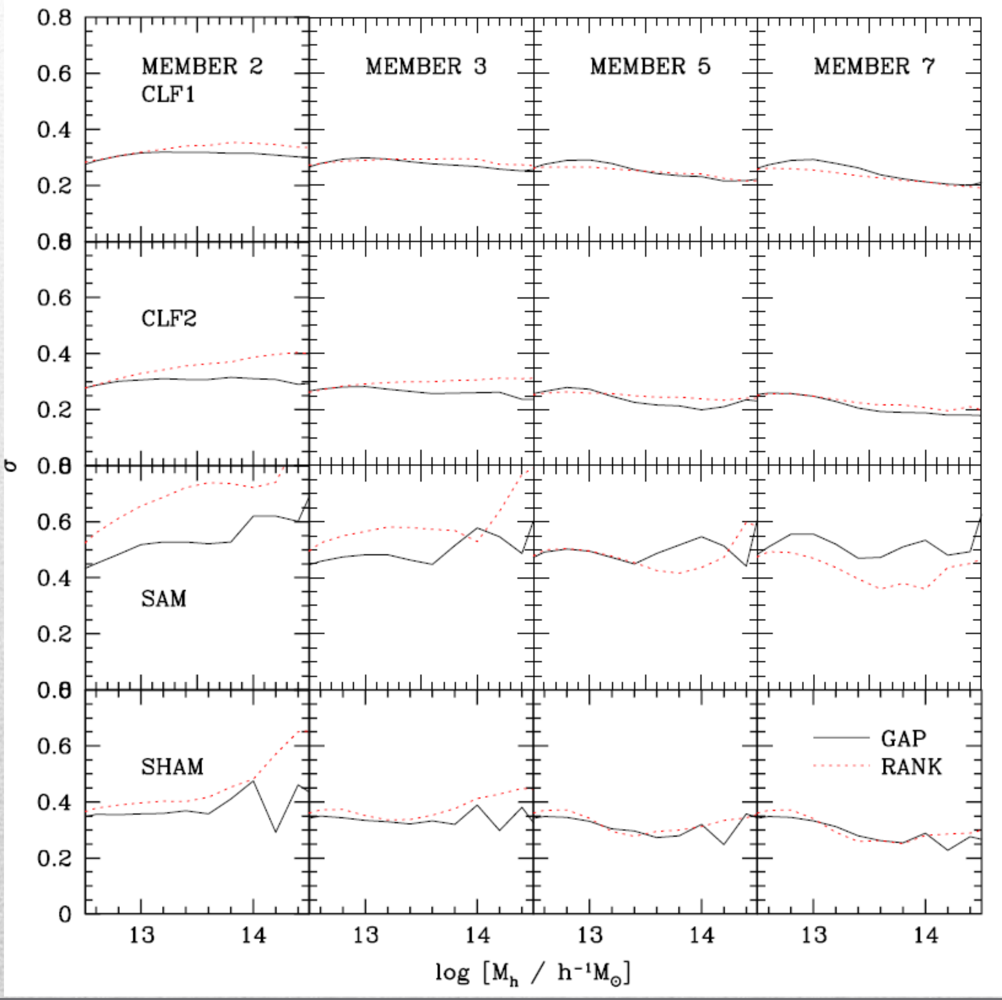
$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(\log M_h - \log M_L)^2}{n-1}}$$





Compare to Other Method (RANK) :

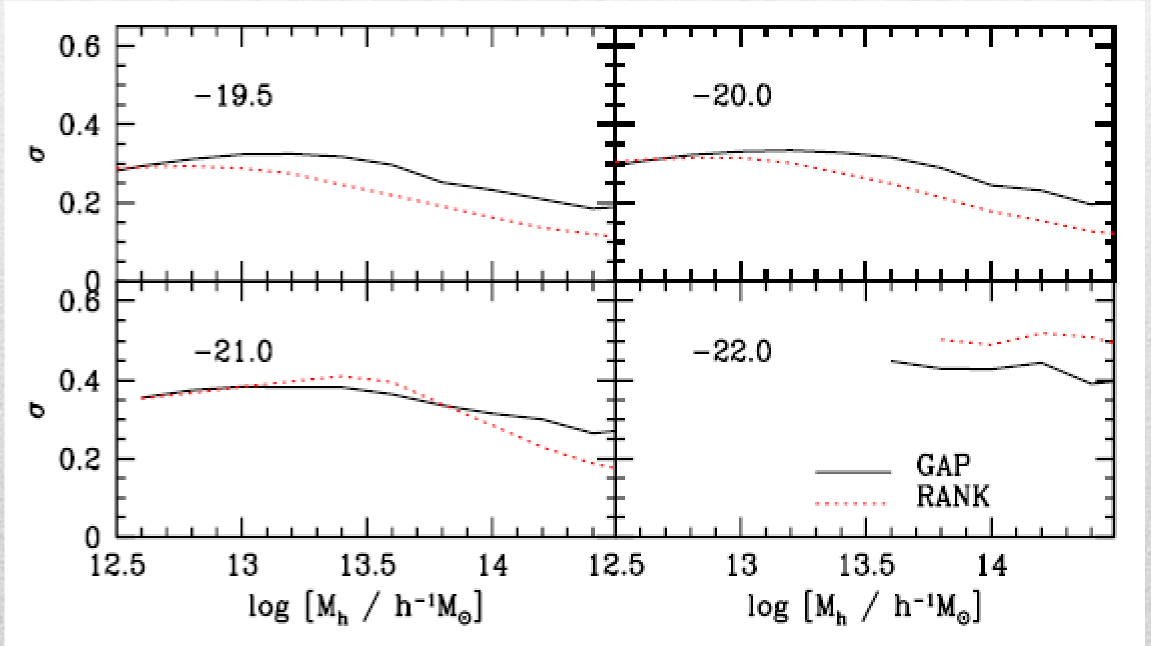
- **Limited richness:**



'RANK' method:
Based on the characteristic group luminosity of member galaxies.
Refer to Yang et al. 2005, 2007 for details.

- **Limited magnitude**:

Based on CLF1 sample
The absolute manitude cuts roughly correspond to redshift:
Z = 0.09, 0.103, 0.157, 0.22 in SDSS with apparent magnitude r=17.6



Summary :

① We find that the median halo mass for a given central galaxy luminosity can be described by simple relation, however with quite large scatter around this median.

② The scatter in the halo mass depends both on the central galaxy luminosity and the luminosity gap between the central and the subsequent brightest member galaxies.

③We have obtained a mass correction factor which is independent to the detailed galaxy formation models, and thus can be applied to any median halo mass - central galaxy luminosity (Mh-Lc) relation to get better estimation of the halo masses.

④ The correction factors can reduce the scatters in halo mass estimations in massive halos by about 50\% to 70\% depend on which member (second or seventh) galaxies are used.

⑤ Comparing this `GAP' method with traditional `RANK' method, we find that the former performs better for groups with less than five members, or in observations with very bright magnitude cut. In addition, the `GAP' method does not need to calculate the volume in estimating halo masses, and thus is much easier to be applied to observations with very small volume or with poor geometry.

THE END .

Thanks!