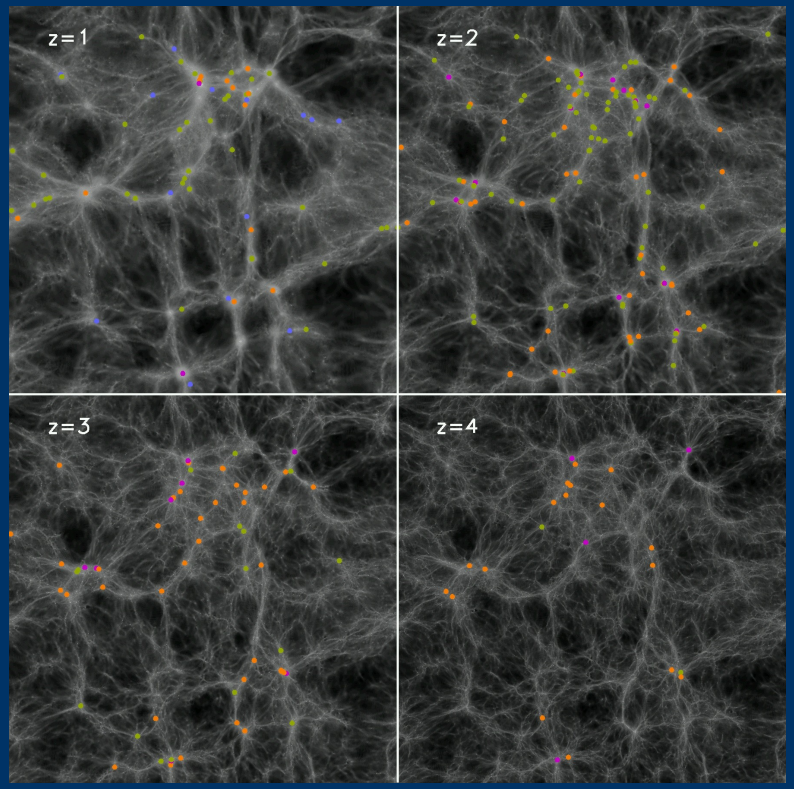
Small Scale Black Hole Clustering in Hydrodynamic Simulations: Evidence for Mergers



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Great Lakes Cosmology Workshop
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DeGraf C., Di Matteo, T., Springel V., 2010, ArXiv: 1005.1653

Outline

- Basic BH properties
- Large Scale Clustering
  - Implications for host halos
- Small Scale Clustering
  - Effect of mergers
- Observational comparison

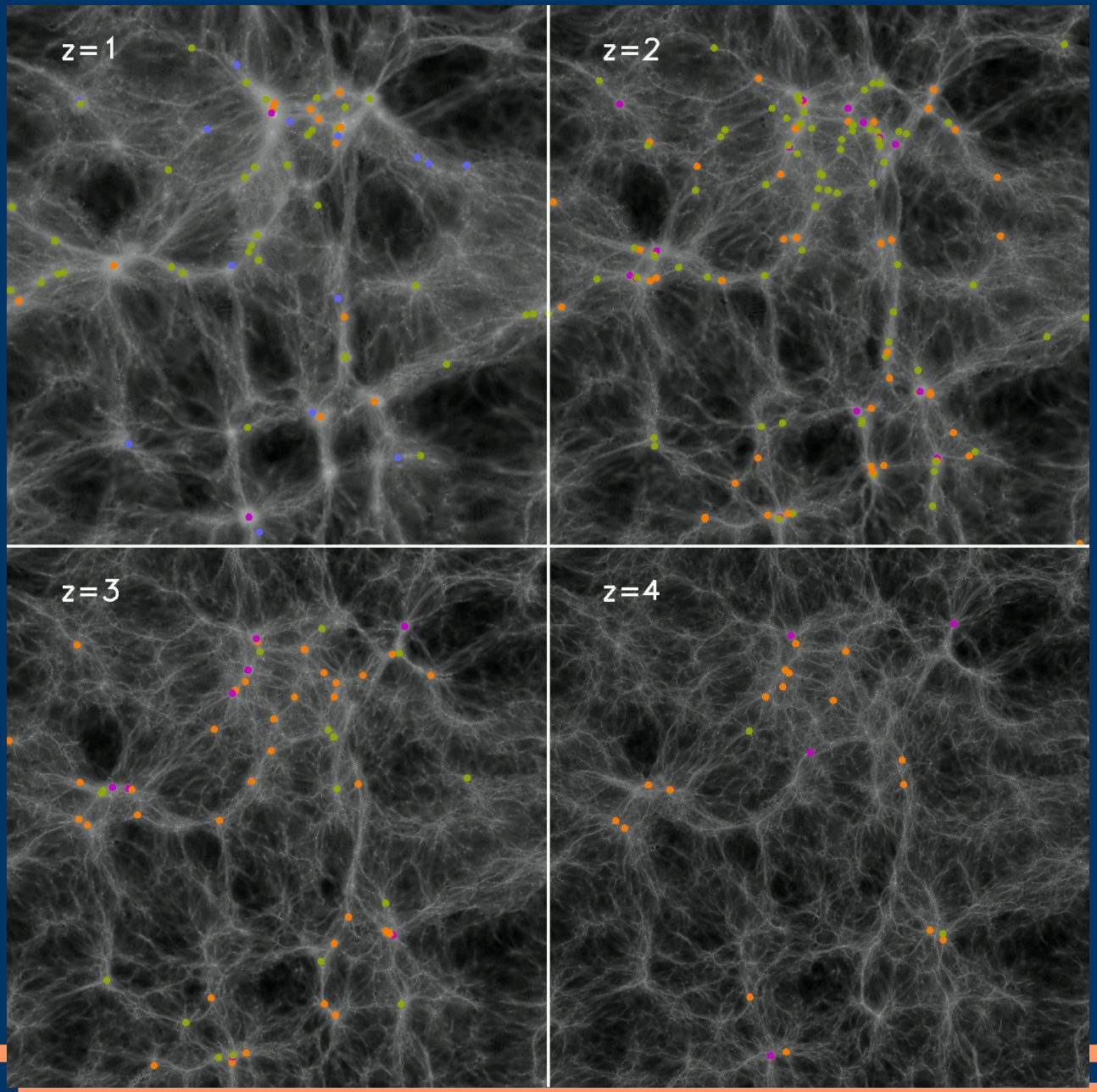
Why clustering?

- Black hole clustering can be matched to observed galaxy clustering, or theorized dark matter clustering
- Strength of clustering helps us understand how BHs populate dark matter halos
- Can be used to make conclusions about BH environment and fundamental processes
  - Ex. Strong clustering -> Large DM halos -> rare objects -> long lifetime
- Luminosity dependence could indicate if bright and faint quasars occupy the same host halos

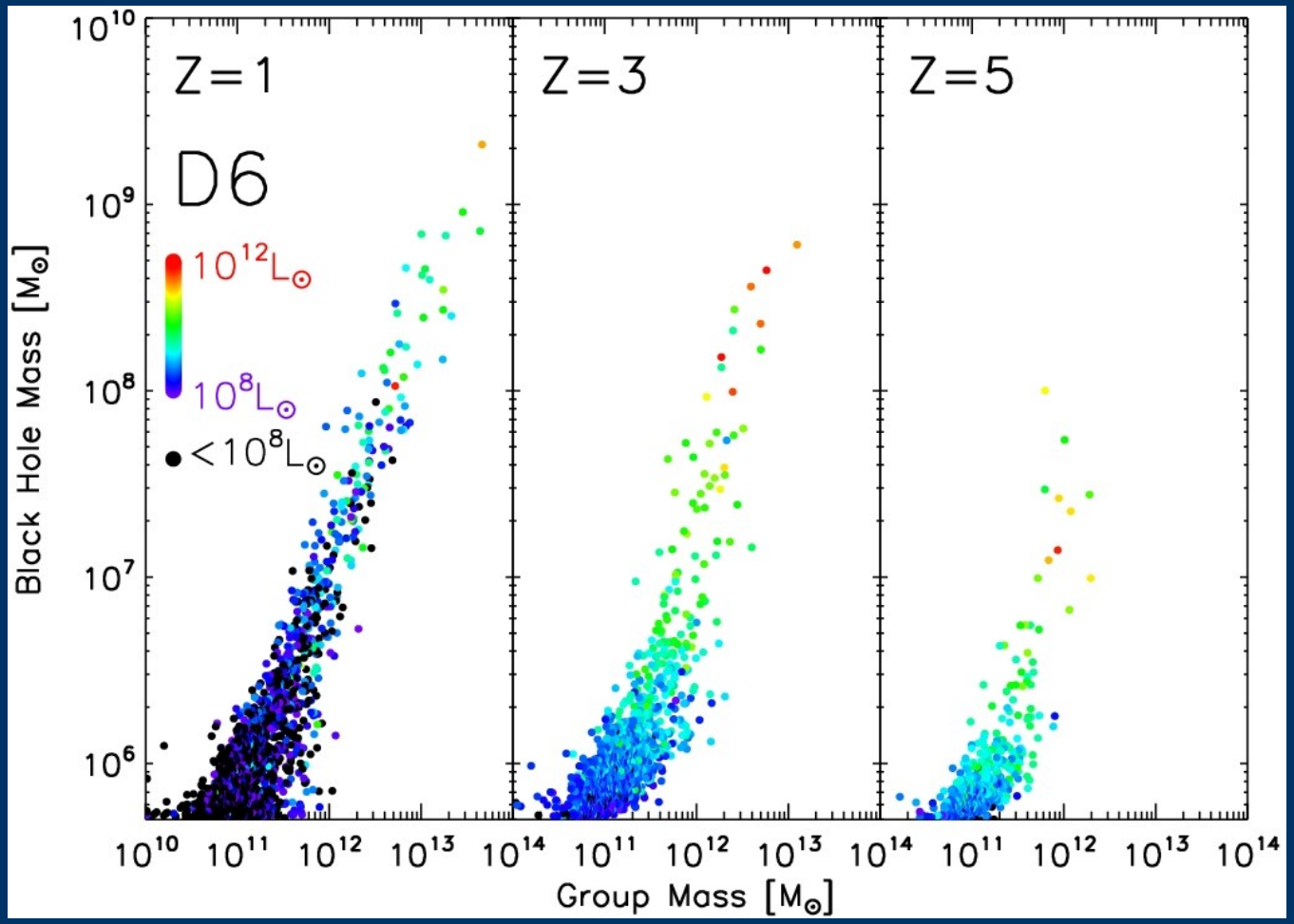
Simulations - Gadget3

- N-body + Hydrodynamics (SPH)
- Subgrid Models
  - Star Formation
  - BH Formation
    - Seeded to groups above $5x10^{10}$ M_O
    - Seed BH: $5x10^5$ M_O sink particle
  - BH Growth
    - Accretion
    - Mergers
  - BH Feedback
- Simulations:
  - 33.75-50.0 Mpc h^{-1}
  - 2.73 kpc h^{-1} softening length
  - $2x486^3$ particles
    - Dark Matter: $2.75x10^7$ M_o ; Gas: $4.24x10^6$ M_o

Our Black Holes



Our Black Holes

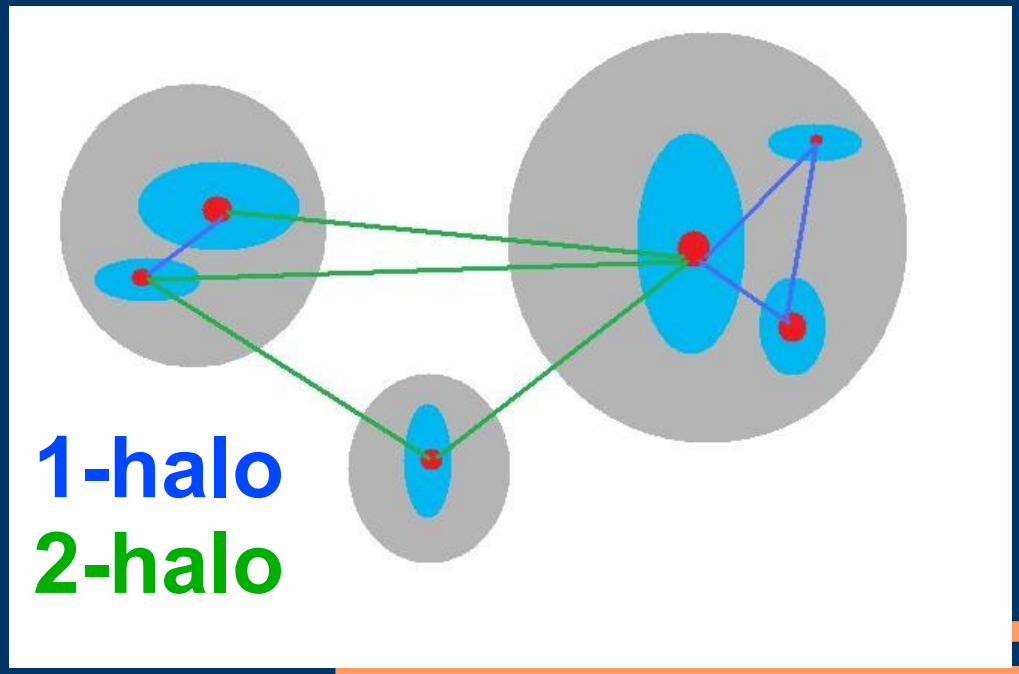


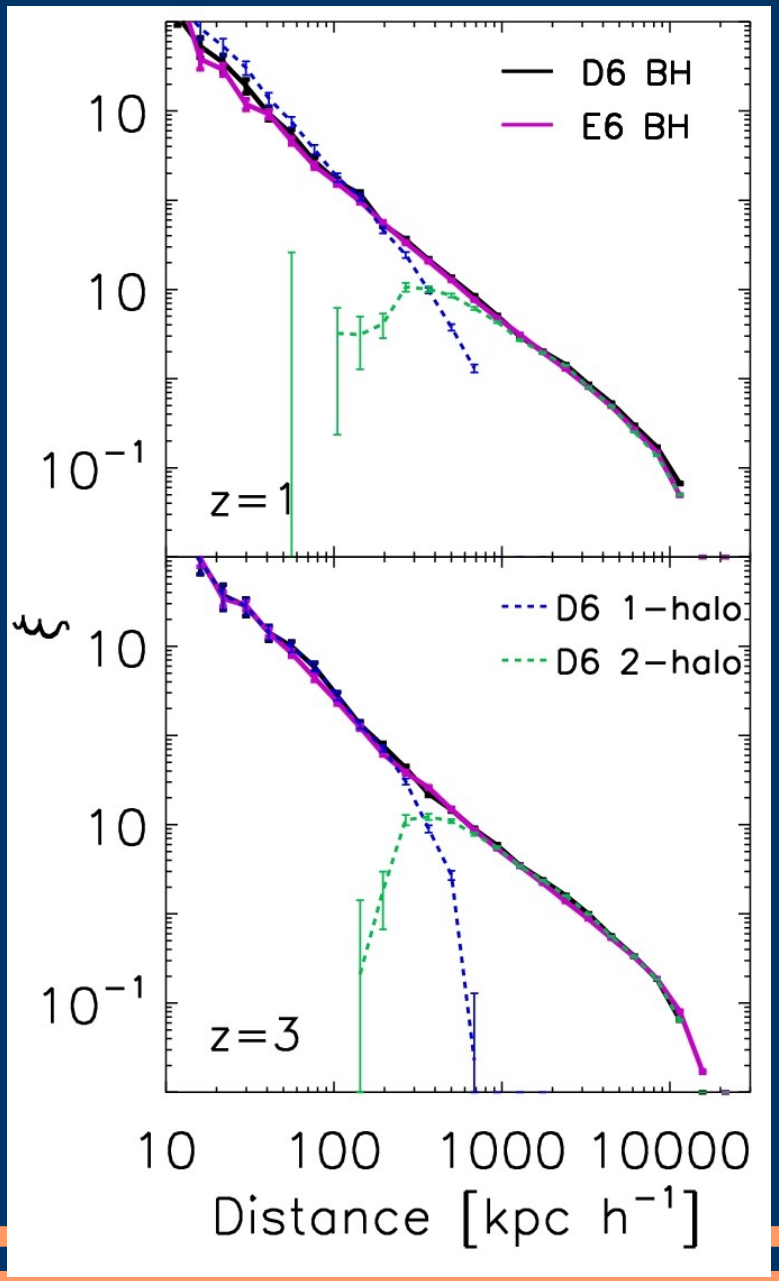
Overall trends with time:

- Increasing number of Bhs
- BHs and groups grow
- Luminosity tends to decrease

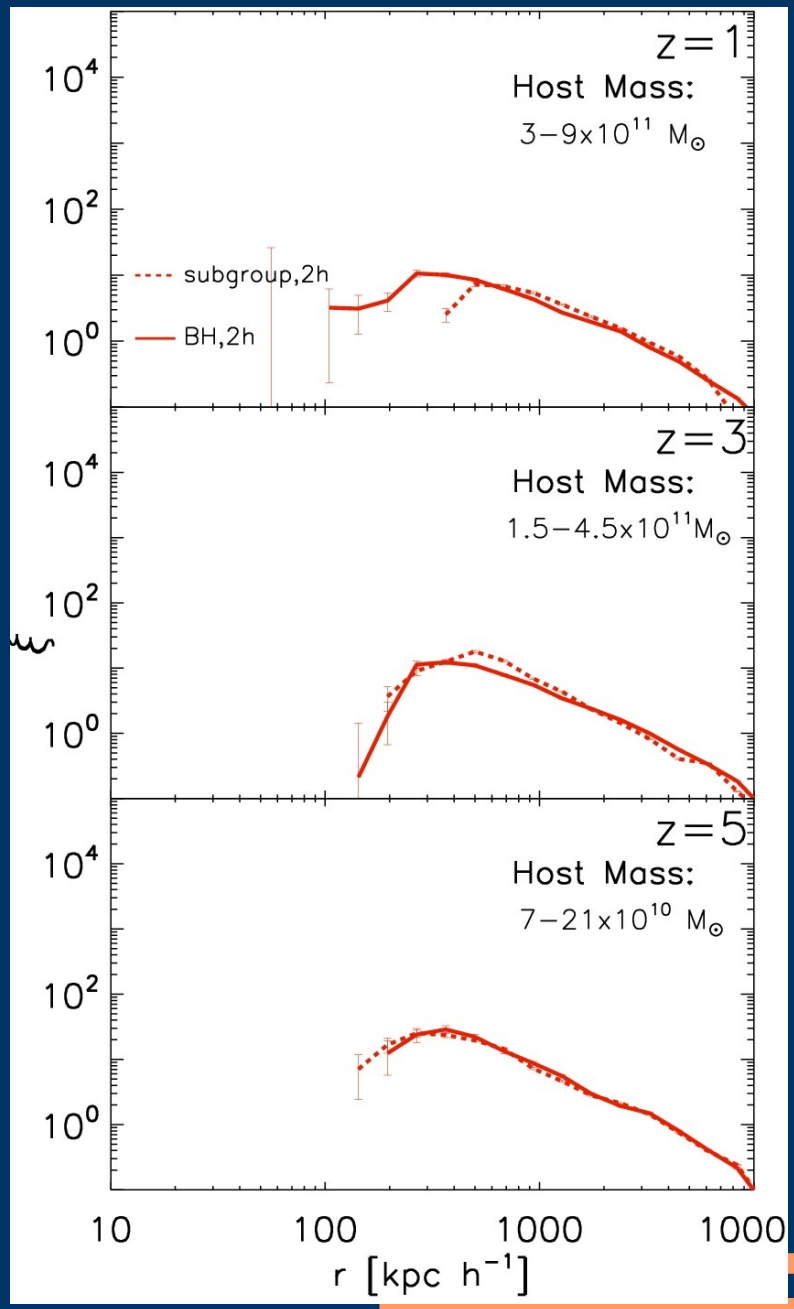
Black hole correlation function

- Good agreement between two simulations
- Distinct 1-halo and 2-halo terms
- 1-halo dominates below ~300 kpc h^{-1}



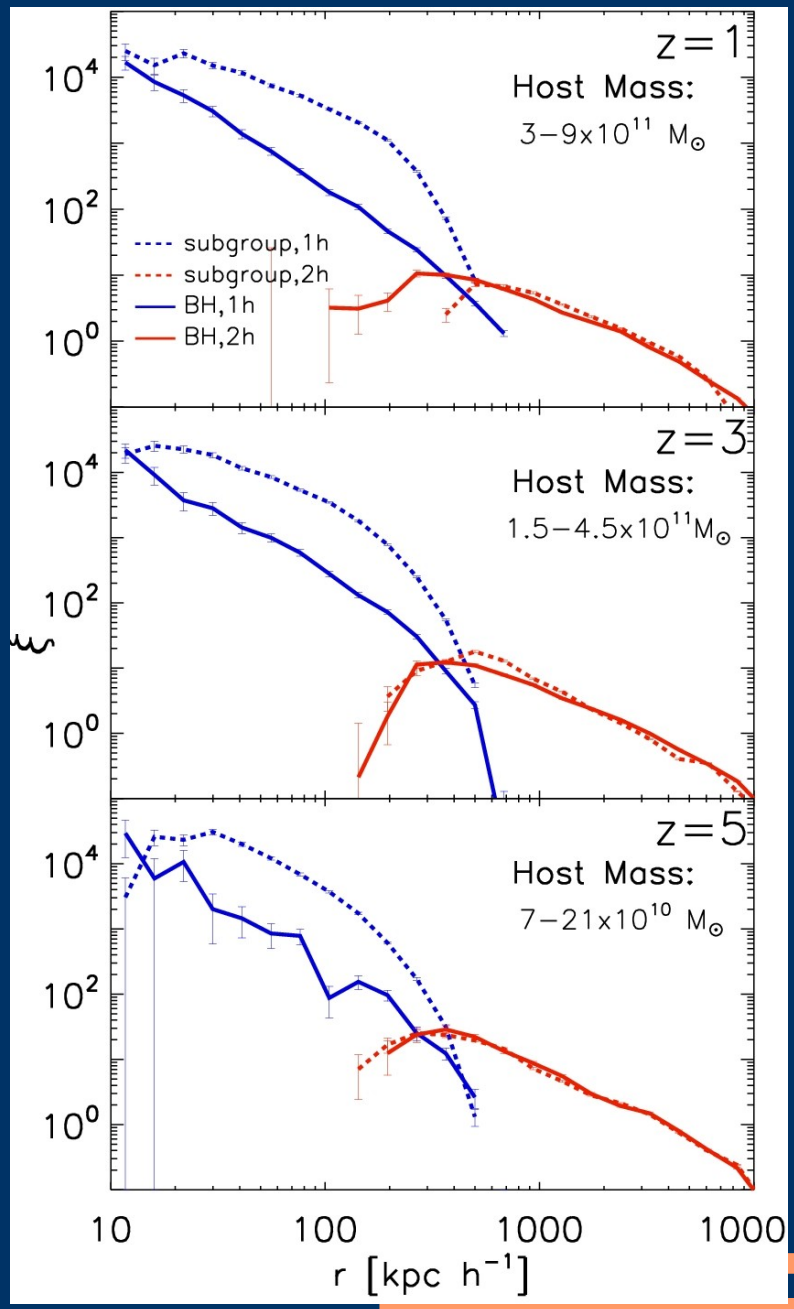


Matching Black Holes to Host Groups



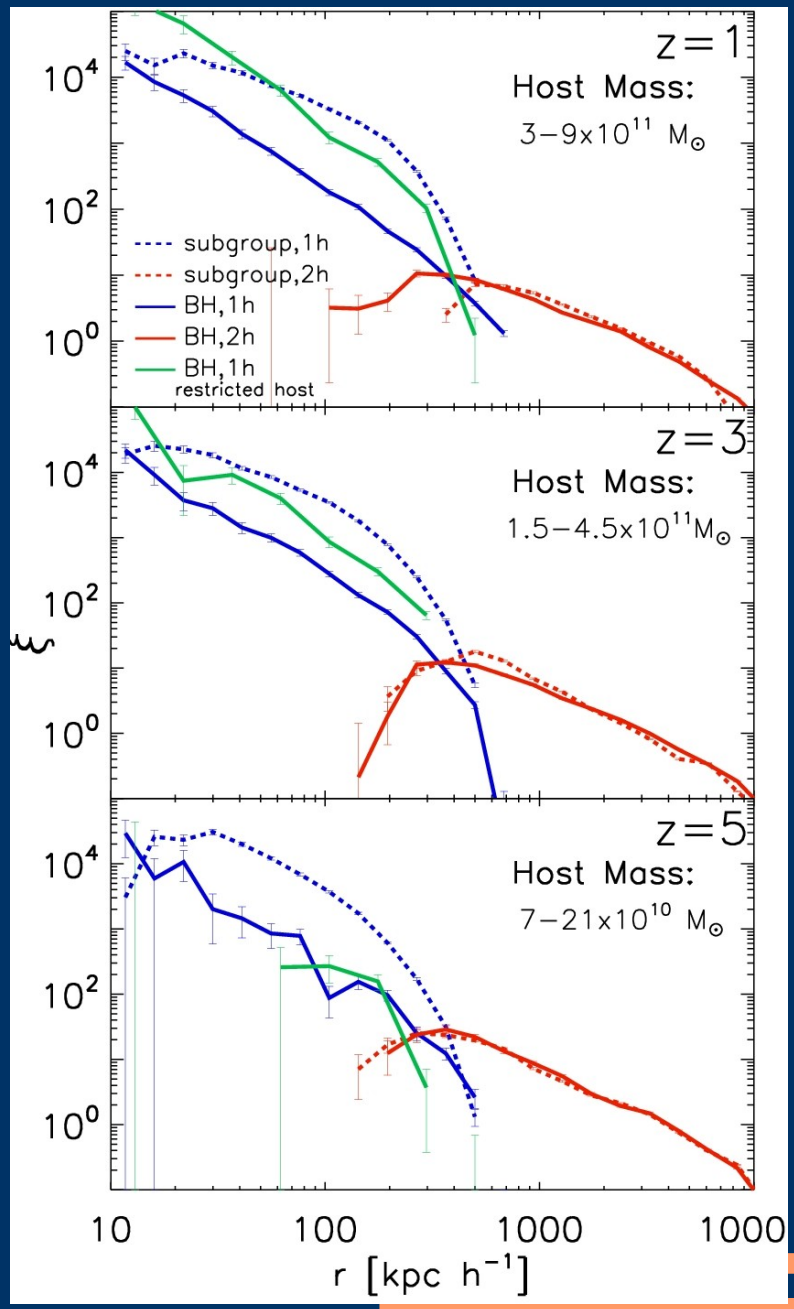
- Typical host mass found by matching 2-halo correlation functions for BHs and groups
  - BHs closely trace group clustering
- Slow evolution for full population
- Rapid increase at low redshift for luminous BHs

Small Scale Clustering



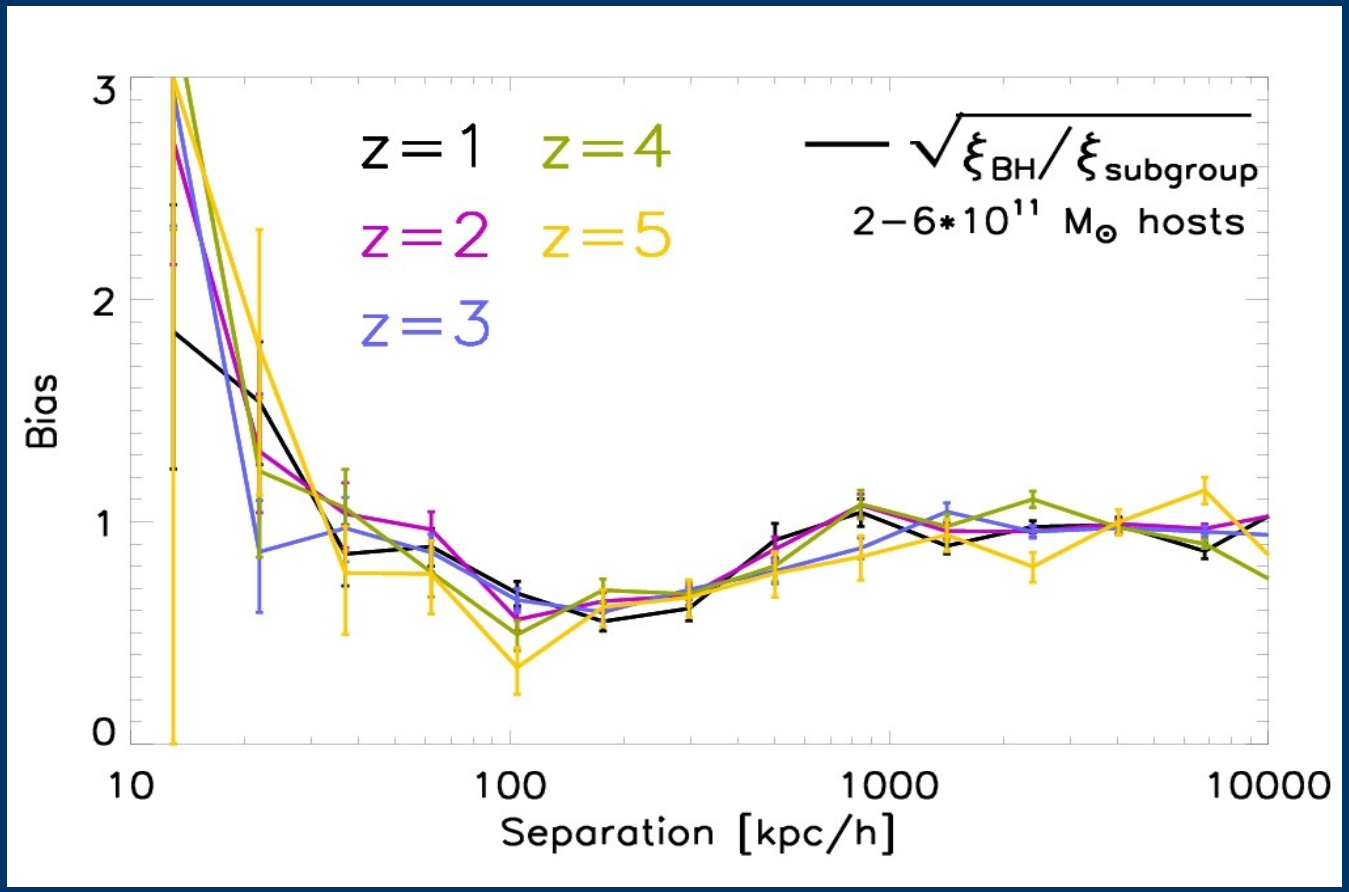
- 1-halo term do <u>not</u> agree

Small Scale Clustering



- 1-halo term do <u>not</u> agree
- Improved agreement if restricted to objects within the same host groups
  - Still different shape

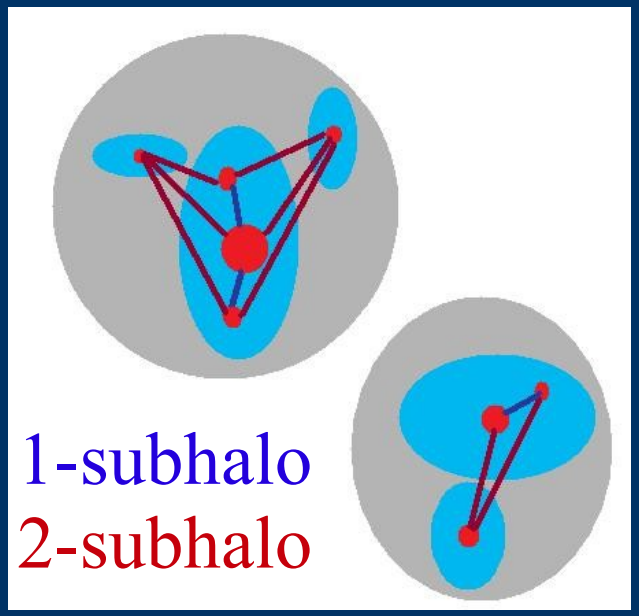
Small Scale Bias



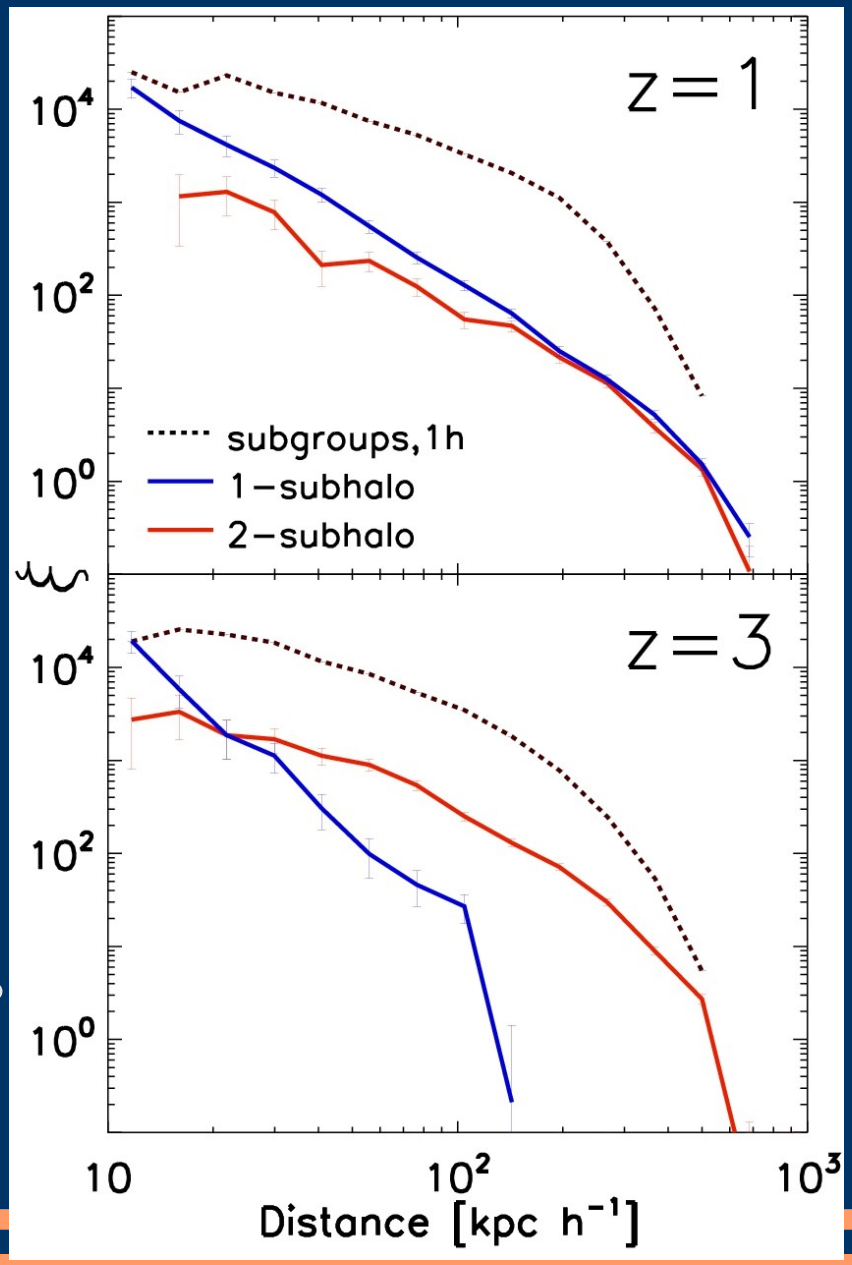
$$\sqrt{\frac{\xi_{BH}}{\xi_{galaxy}}}$$

- Boost in small scale bias
  - In sufficiently large groups
  - At all redshifts

Small Scale Clustering



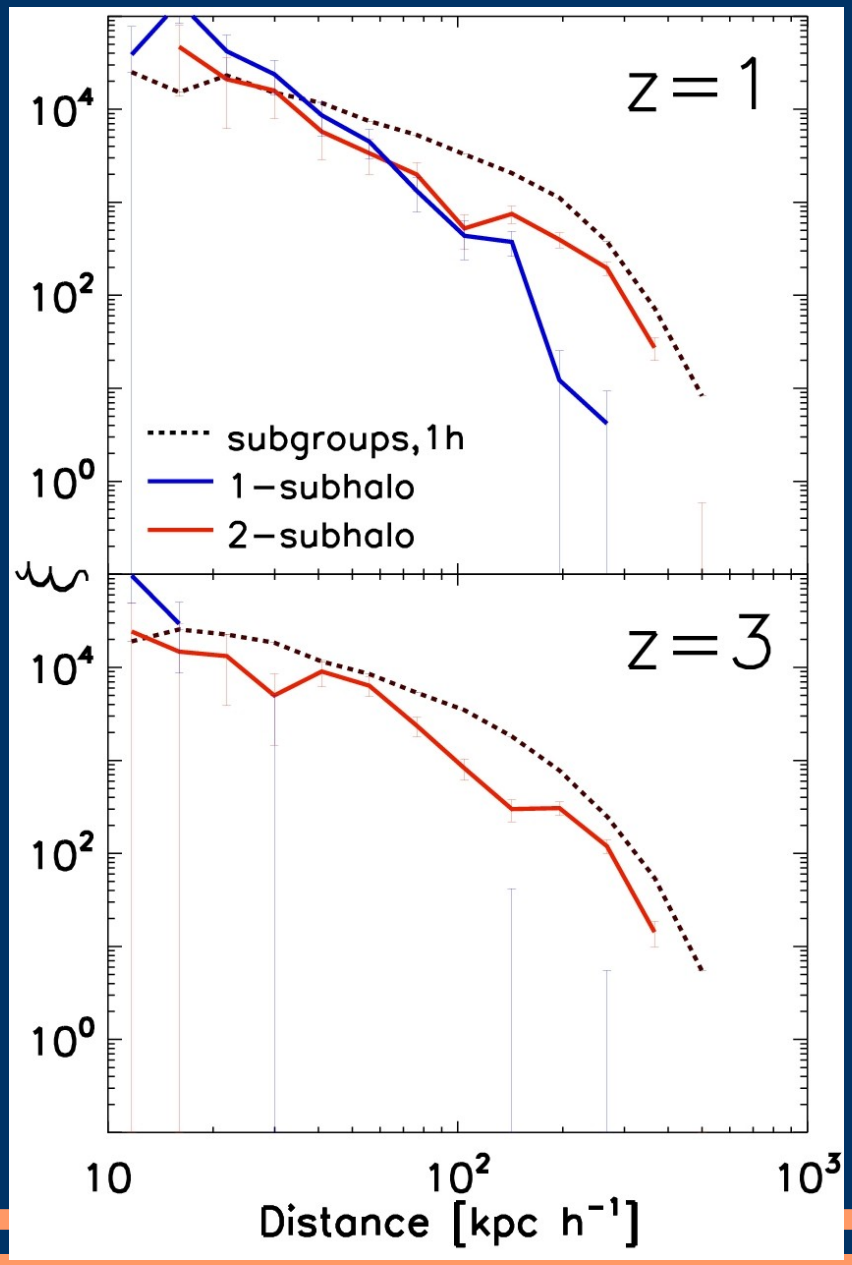
- Subdivide 1-halo into '1-subhalo' and '2-subhalo'



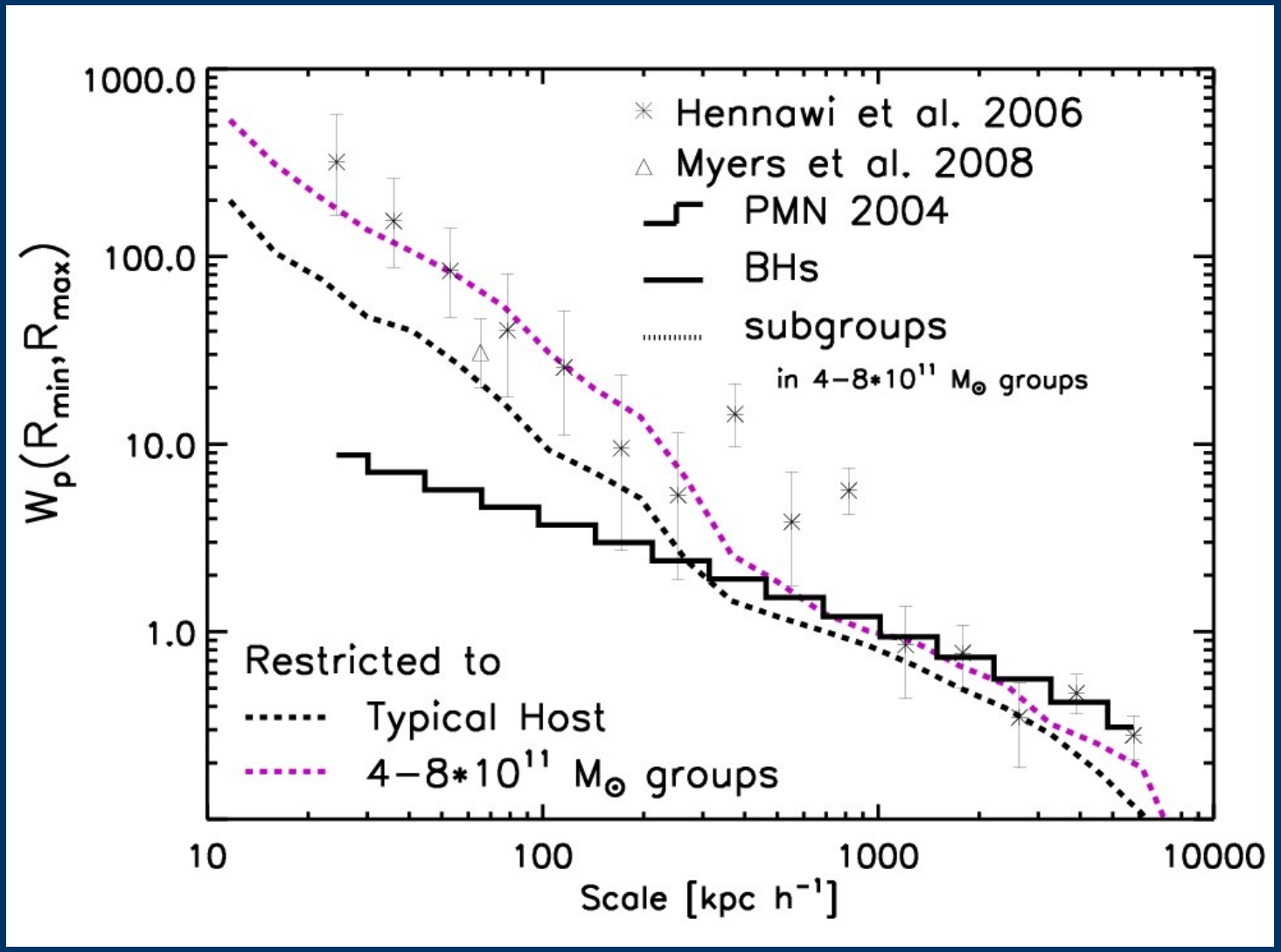
- 1-subhalo term:
  - BH pairs in single galaxy
  - Results of galaxy interactions/mergers
  - Most important in largest groups
  - Steepens small scale correlation function

Small Scale Clustering

- Better 2-subhalo agreement when BHs restricted to same host groups as the subgroups



Observational Comparison



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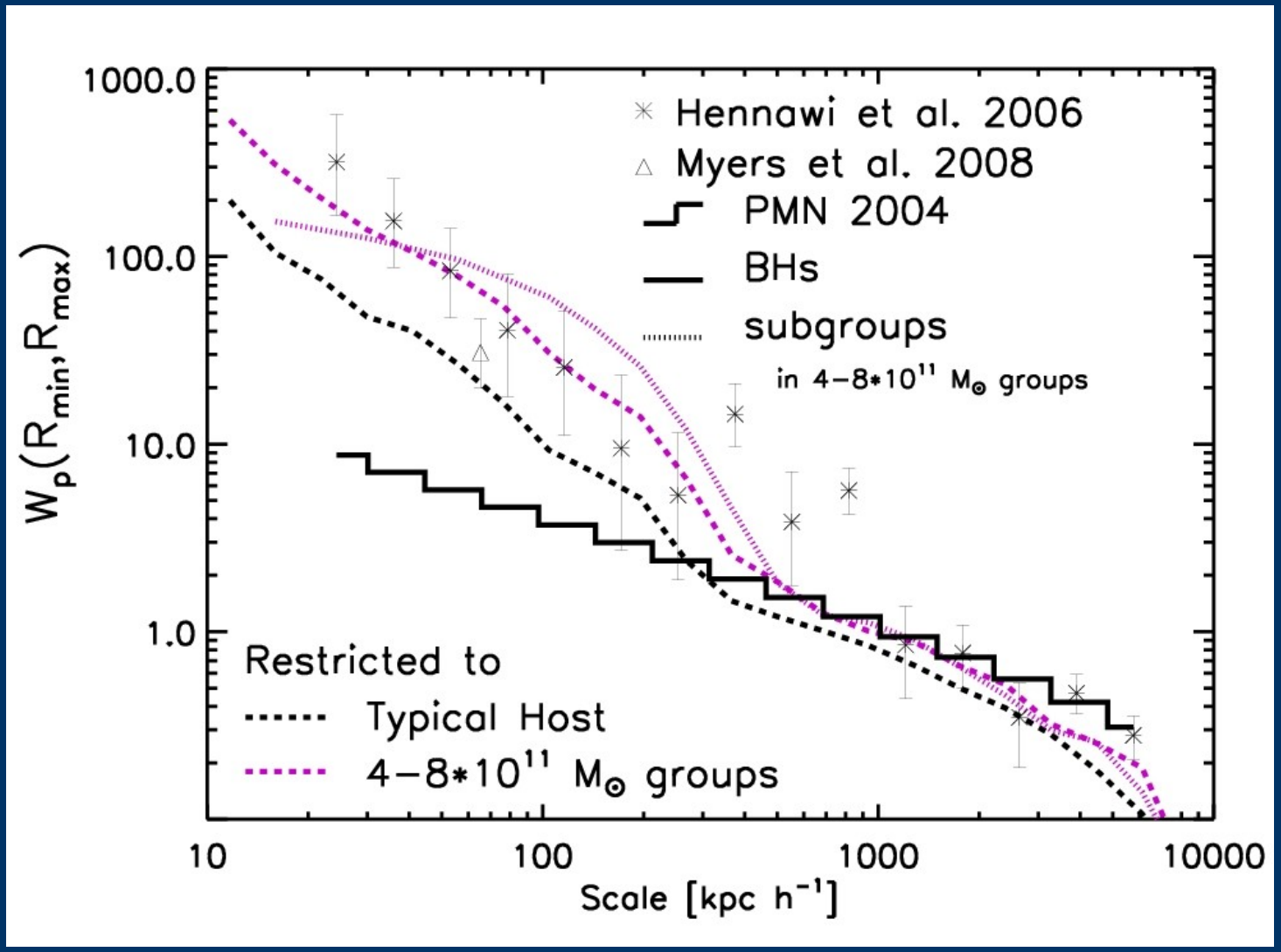

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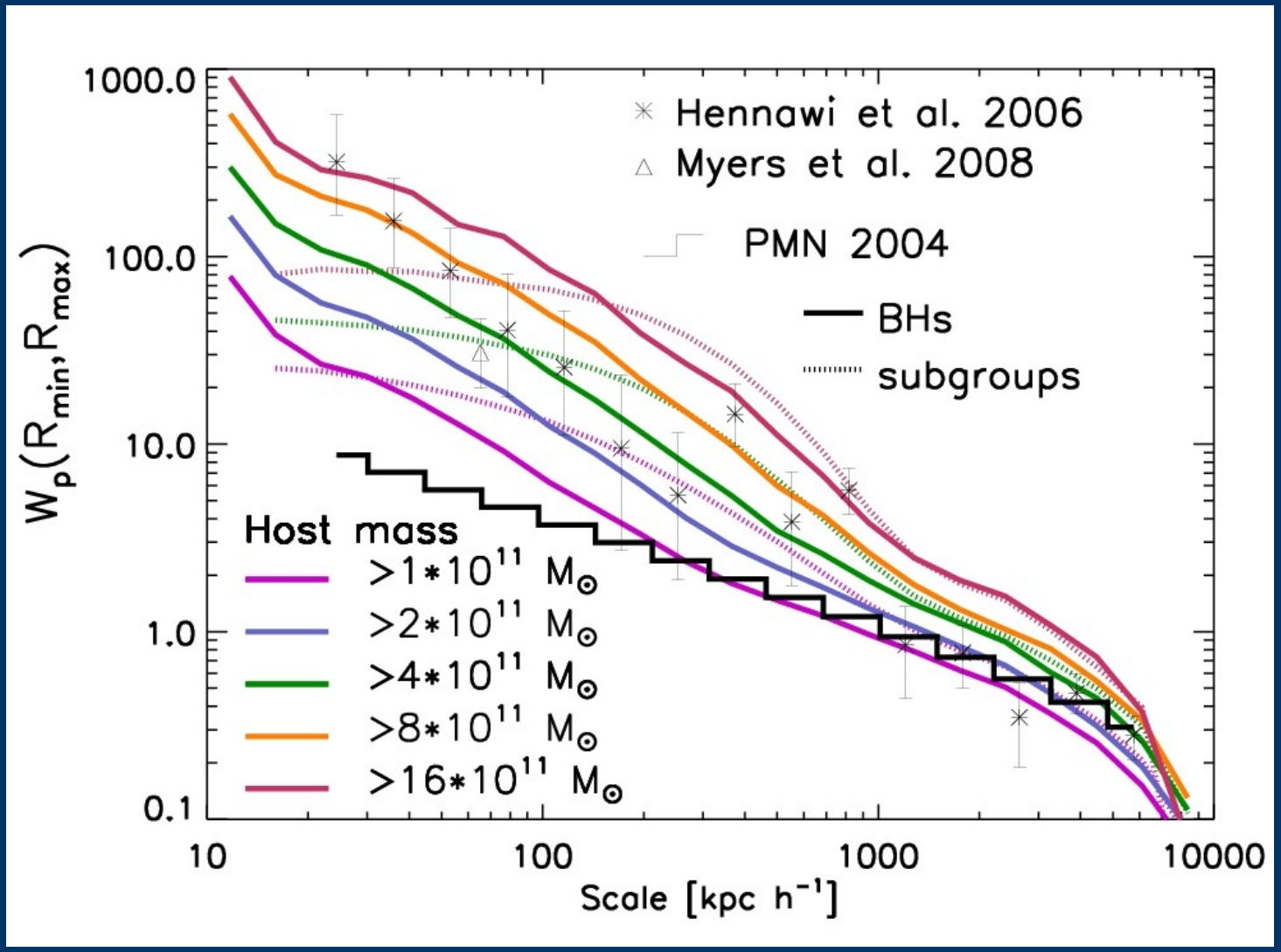
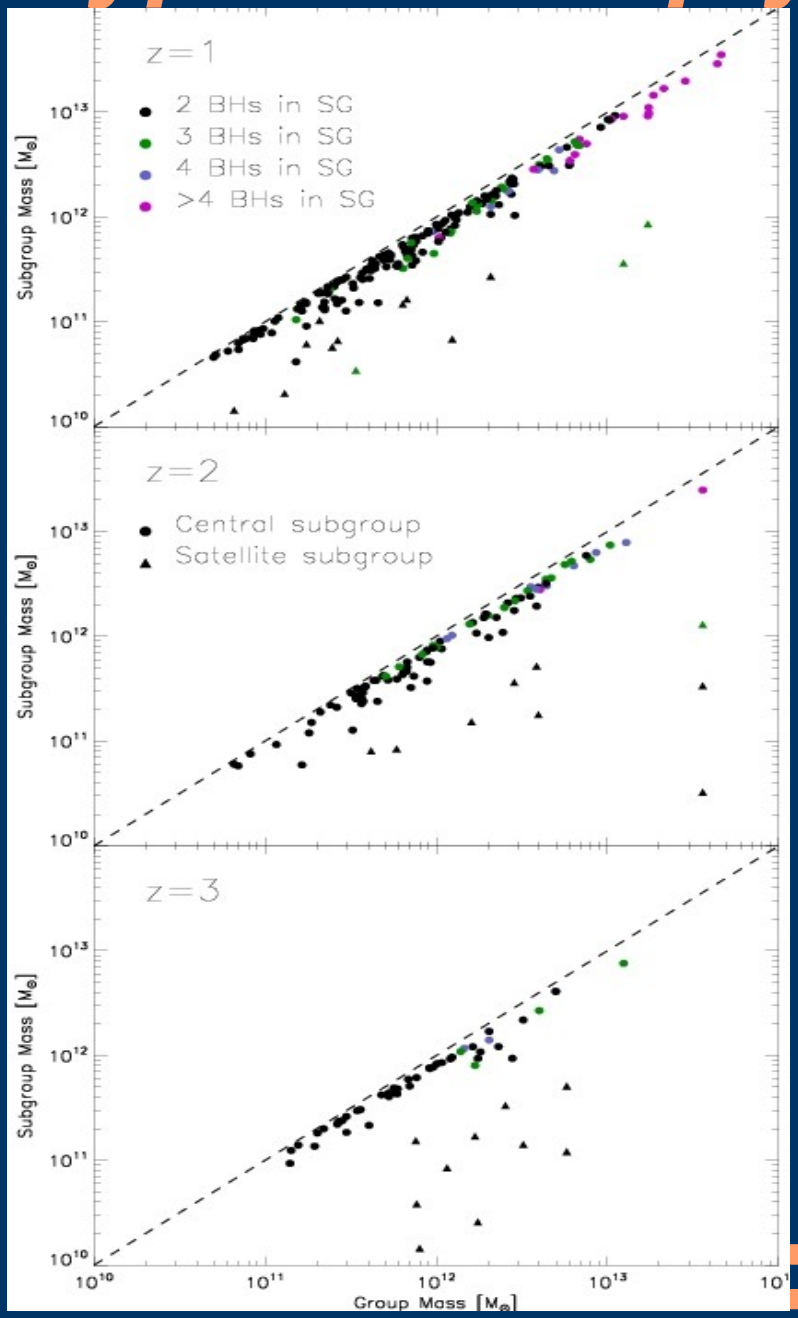


Conclusions

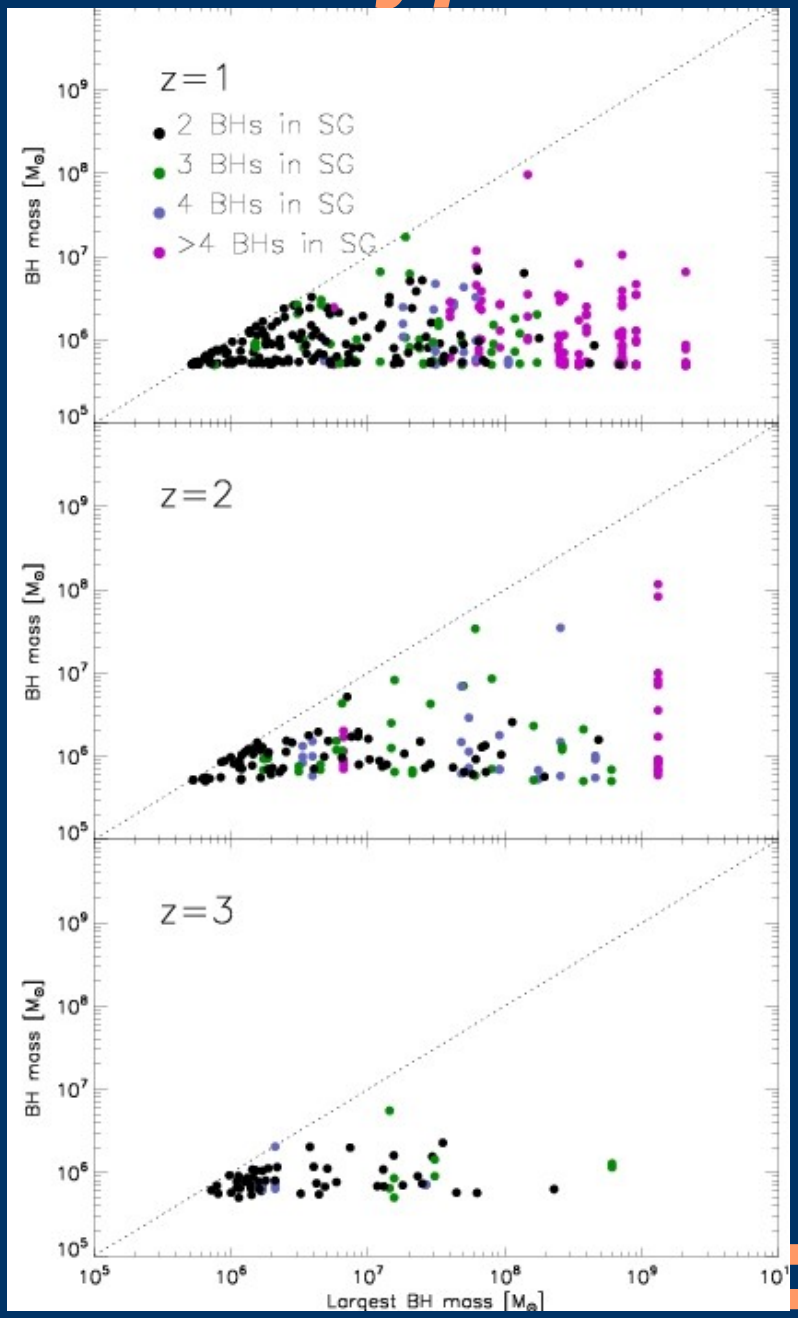
- Large scale clustering matches galaxy clustering
  - Typical host mass increases with time
- Small scale clustering does not match galaxies
  - Caused by merger-induced multiply-occupied galaxies
    - Typically central galaxy
    - Typically no more than one massive BH ($>10^7 M_o$)
  - Explains excess in observed signal
  - Reinforces importance of galaxy interactions on black hole evolution

Typical Multiply-occupied Subgroups



- Much more common at low redshift
- Larger groups tend to host more BHs in central SG
- Almost exclusively central subgroups

Typical Co-habitating BHs



- Much more common at low redshift
- Larger groups tend to host more BHs in central SG
- Generally one massive BH with one or more smaller BHs