Evidence of Halo Assembly Bias in Massive Clusters

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MENU

Galaxy Clusters Reveal New Dark Matter Insights

This comparison of galaxy clusters from the Sloan Digital Sky Survey DR8 galaxy catalog shows a spread-out cluster (left) and a more densely-packed cluster (right). A new study shows that these differences are related to the surrounding dark-matter environment. Credit: Sloan Digital Sky Survey

› Larger image

Popular

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Outline

- Motivation and introduction to assembly bias
- Measurement of assembly bias
- Summary and future directions

Dark Sector of the Universe

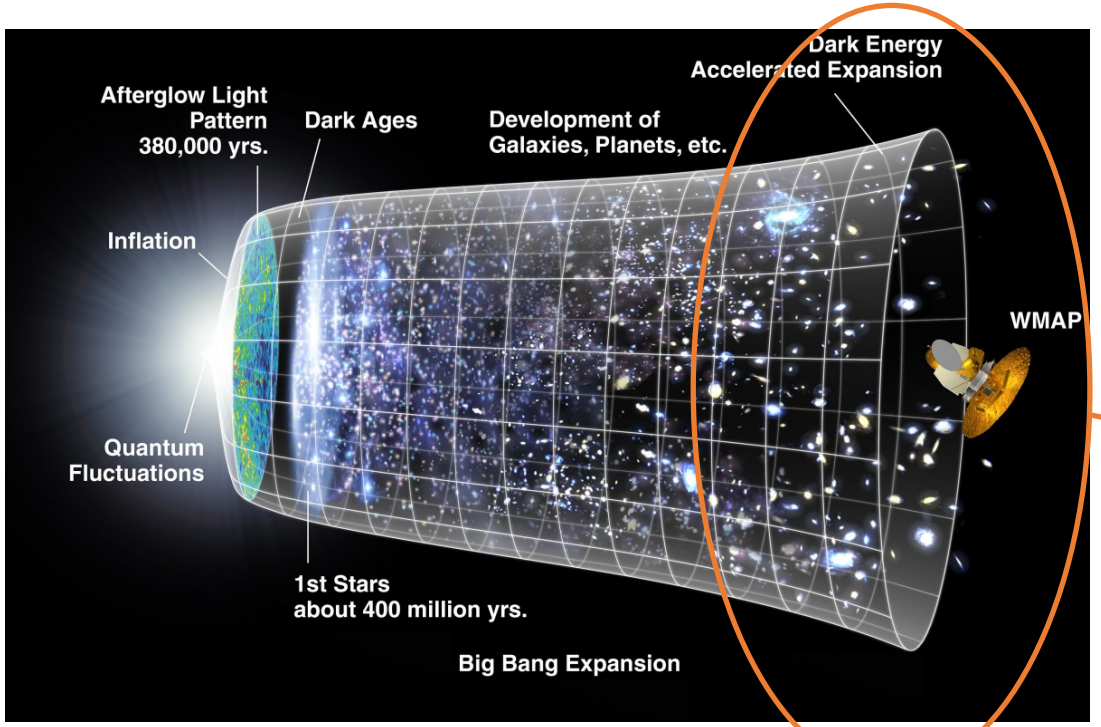


Image credit: NASA/WMAP Science Team

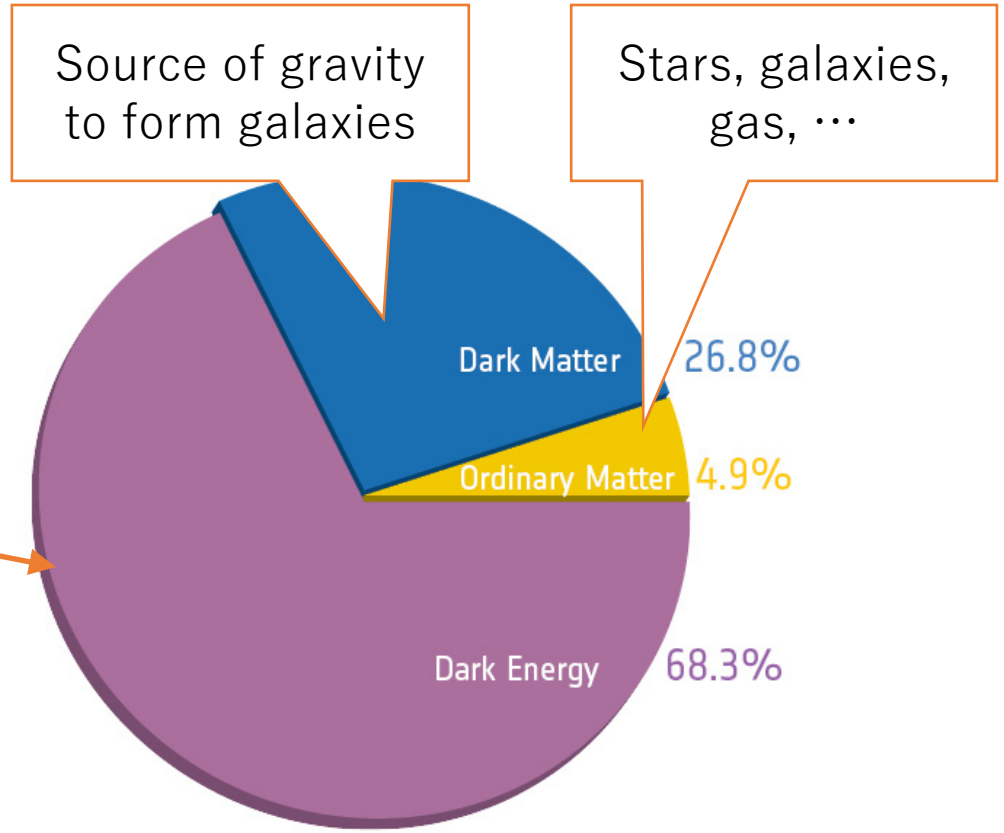
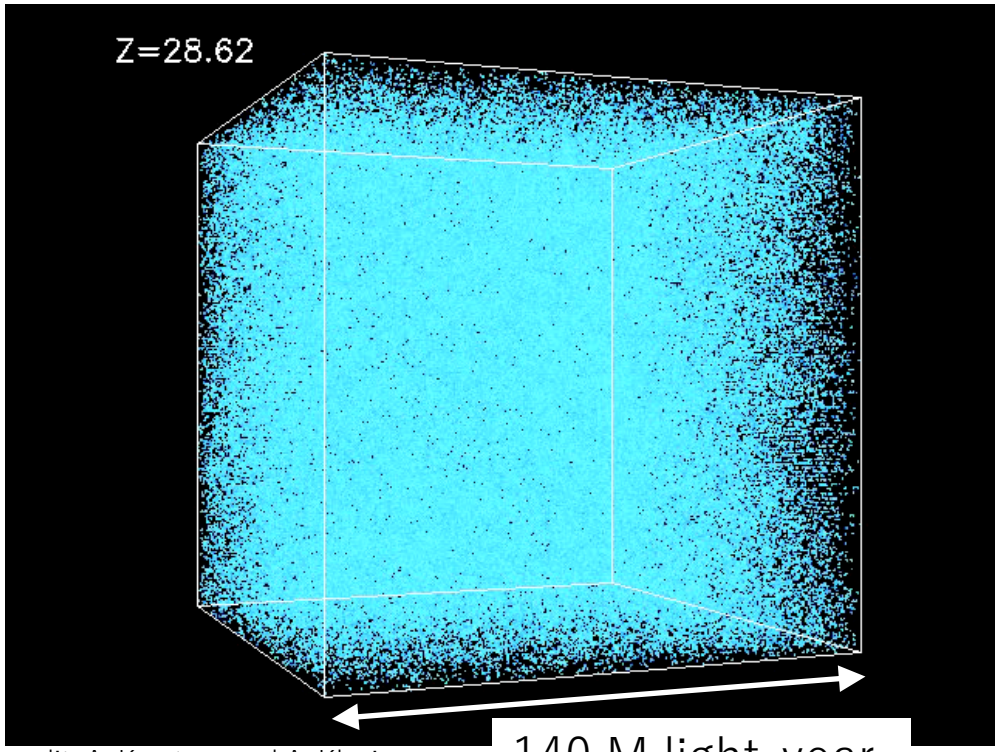


Image credit: ESA/Planck

What is dark matter? What is dark energy?

Dark Sector of the Universe

Formation of the structure of the universe



credit: A. Kravtsov and A. Klypin

140 M light-year

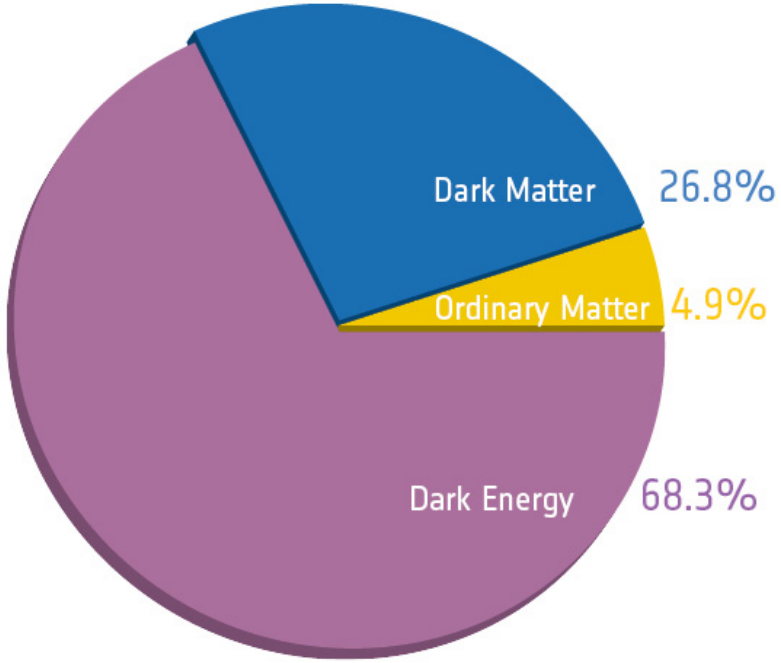
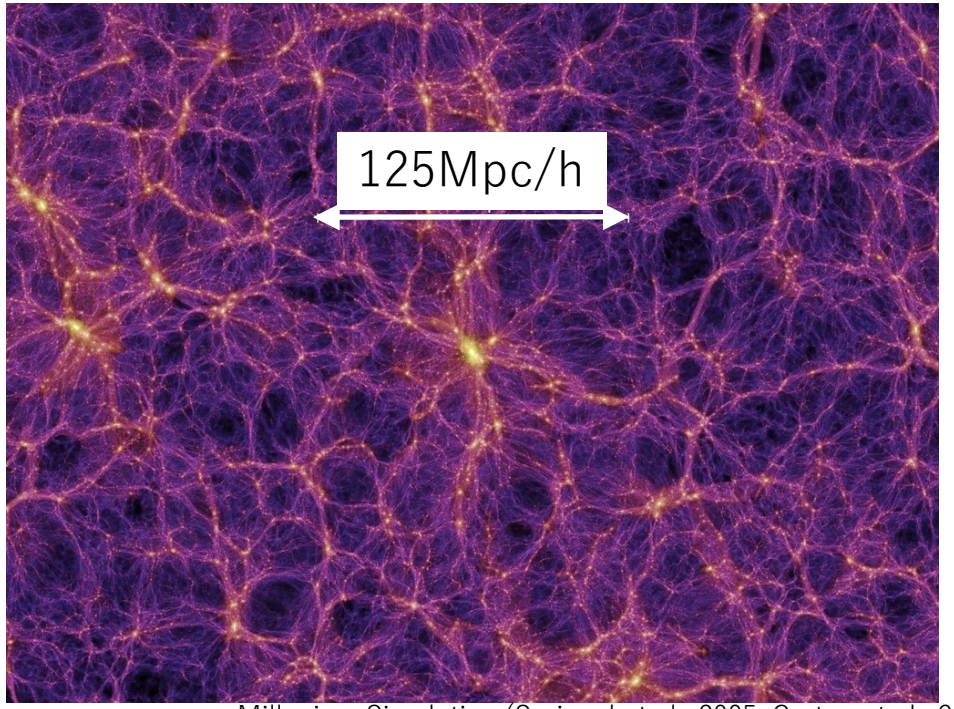


Image credit: ESA/Planck

Structure of the Universe is formed in the competition between dark matter and dark energy

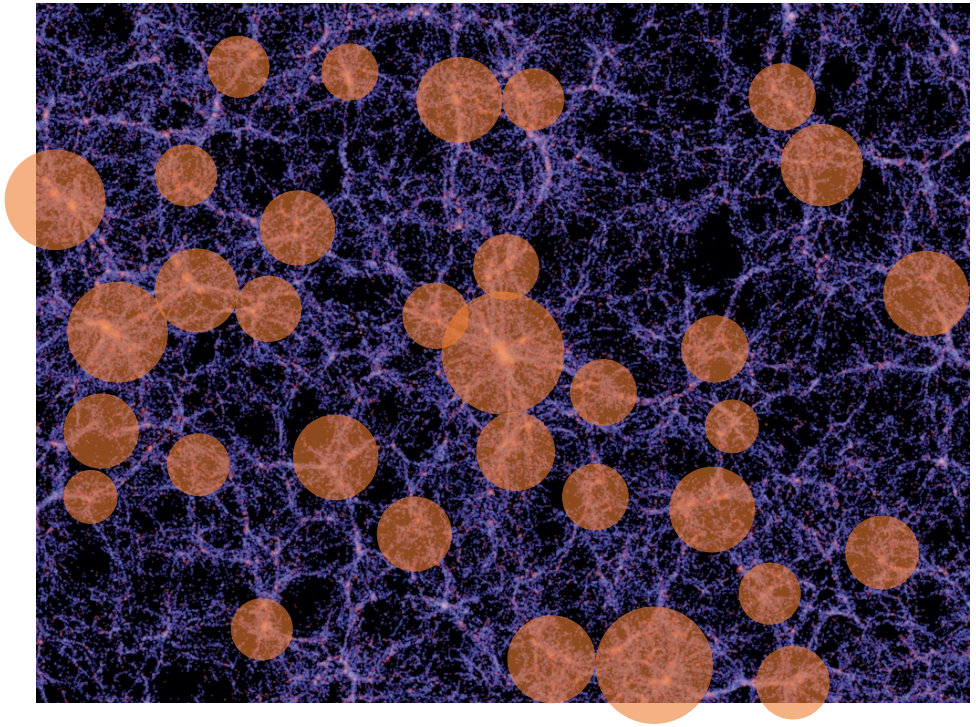
Distribution of Dark Matter vs Galaxy Clusters

Dark Matter



Millenium Simulation (Springel et al., 2005, Croton et al., 2006)

Lights from galaxies

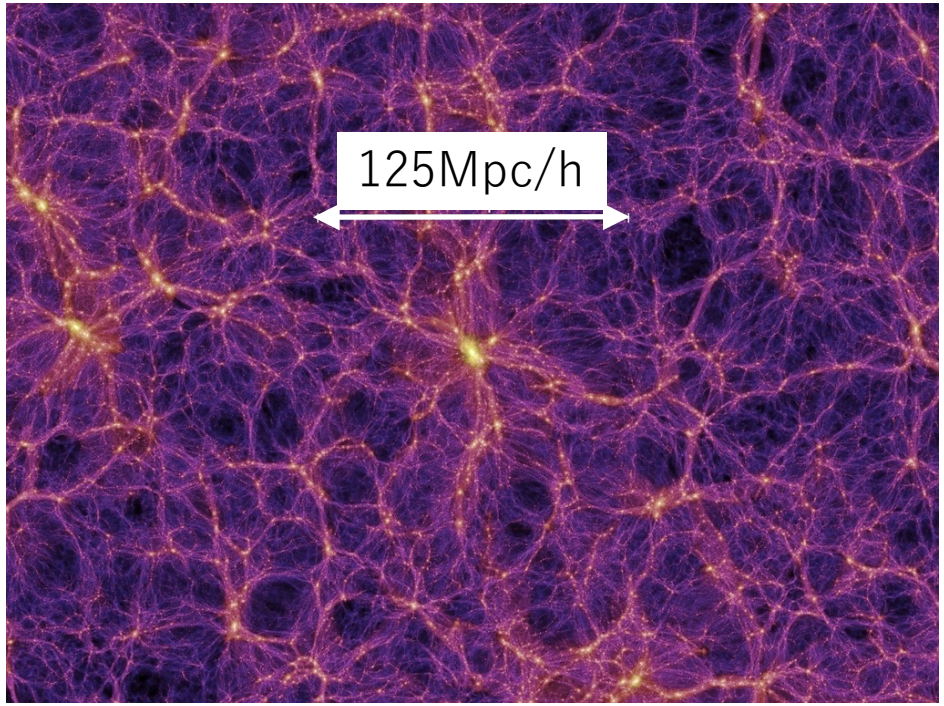


- To extract the information about dark sector, we need to measure dark matter distribution.
- What we can see is galaxies/galaxy clusters, not dark matter.
- We need to infer the dark matter distribution from galaxy/galaxy cluster distribution.

Bias: Relationship between DM and galaxy/cluster distribution

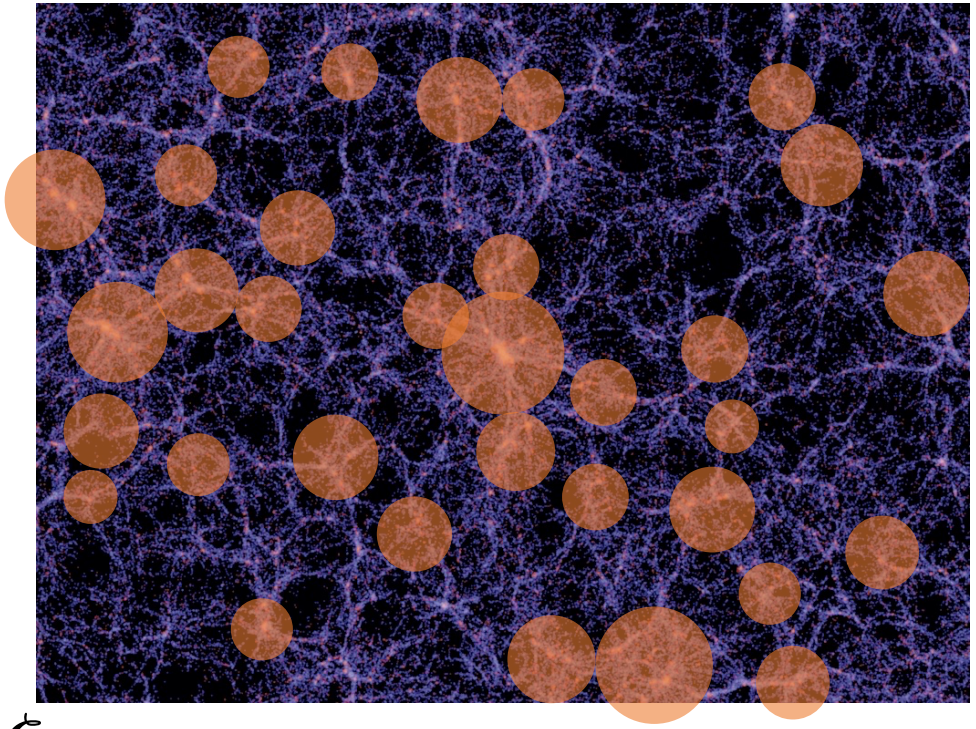
Modeling Bias

Dark Matter



ξ_{mm}: clustering of dark matter

Lights from galaxies



ξ_{hh}: clustering of galaxy clusters

$$\xi_{hh} = \boxed{b}^2 \xi_{mm}$$

bias

Large bias
→ More likely to find neighbors

Assembly Bias

- In observational studies, bias is often assumed to depend ***only*** on the mass of galaxy clusters.
  - Massive galaxy clusters are more clustered → large b

- In theoretical studies, it has been pointed out that bias can depend on assembly history of galaxy clusters such as formation time, mass accretion rate, and steepness of the dark matter halo density profile (***concentration***).

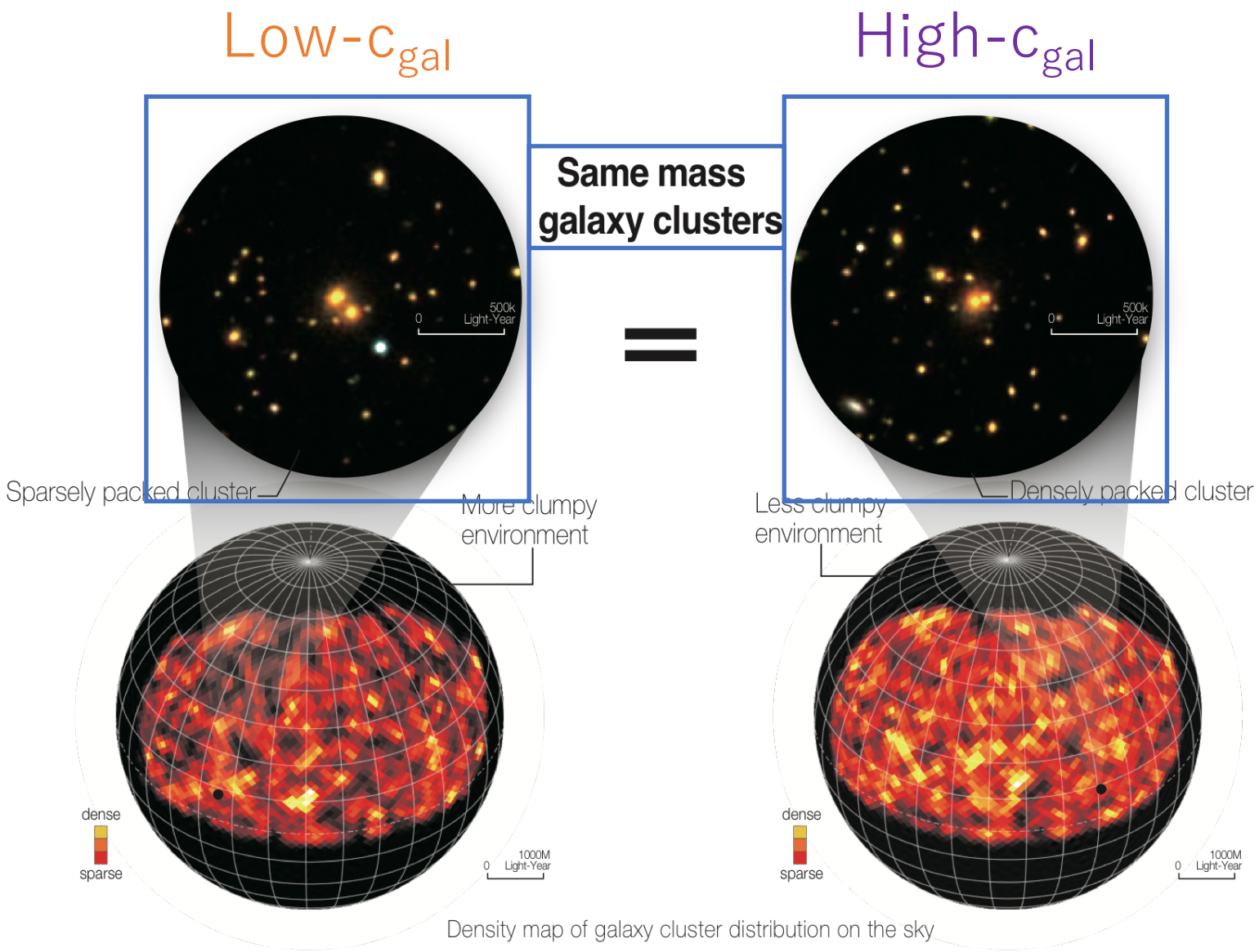
- Such bias is called ***assembly bias***. Ignoring assembly bias results in misestimation of the dark sector information.

- We present the first observational evidence of assembly bias.

Measurement

1. Divide 8,648 galaxy clusters from Sloan Digital Sky Survey (SDSS) into 2 subsamples based on how member galaxies in a cluster are concentrated.

2. Confirm the mass of the subsamples are the same.



Miyatake et al., PRL, 116(4):041301, 2016

Weak Gravitational Lensing

- Mass structure (including dark matter) distorts shapes of distant galaxies.
- Weak lensing gives an unbiased estimate of cluster mass.

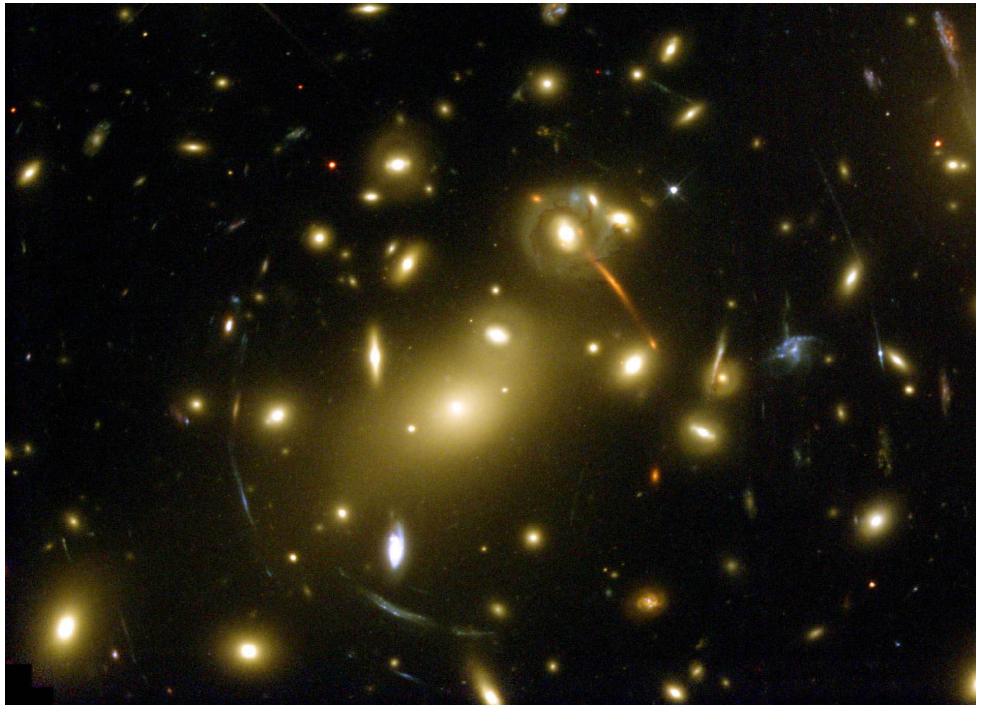
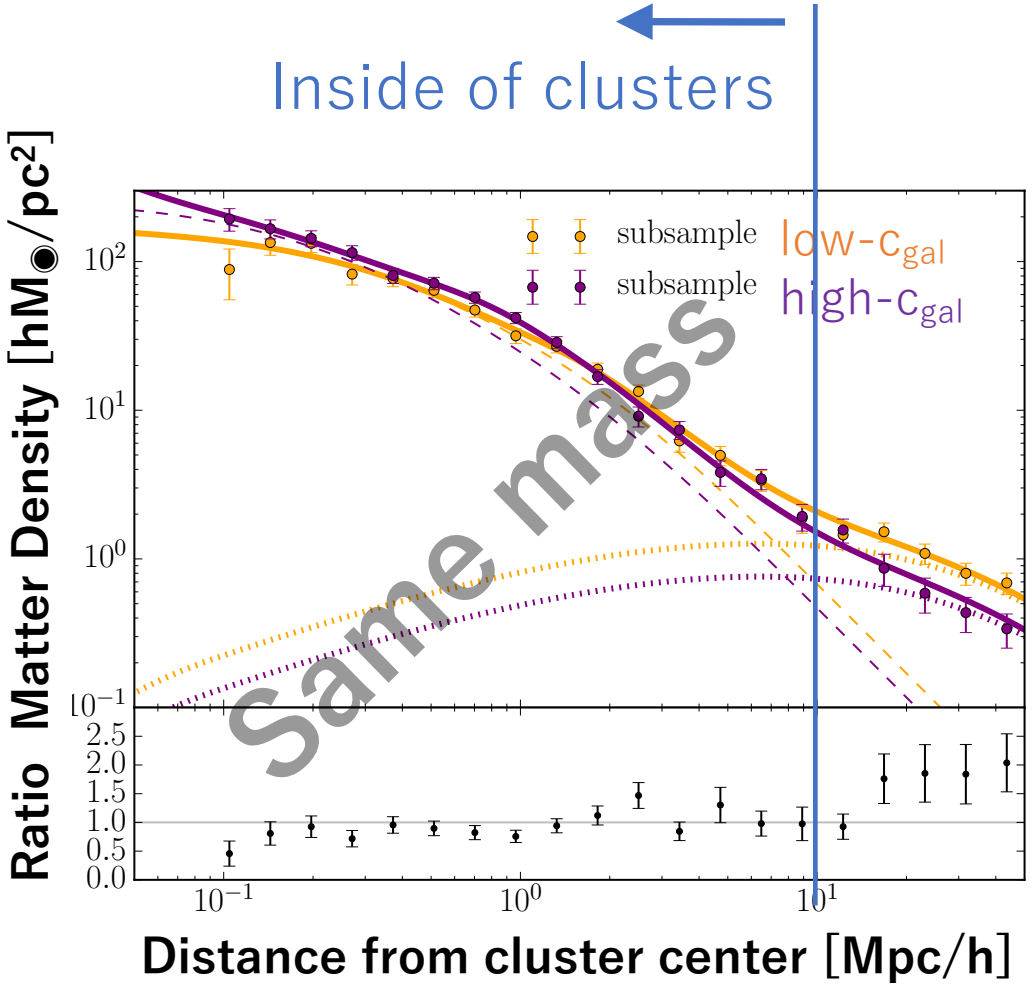
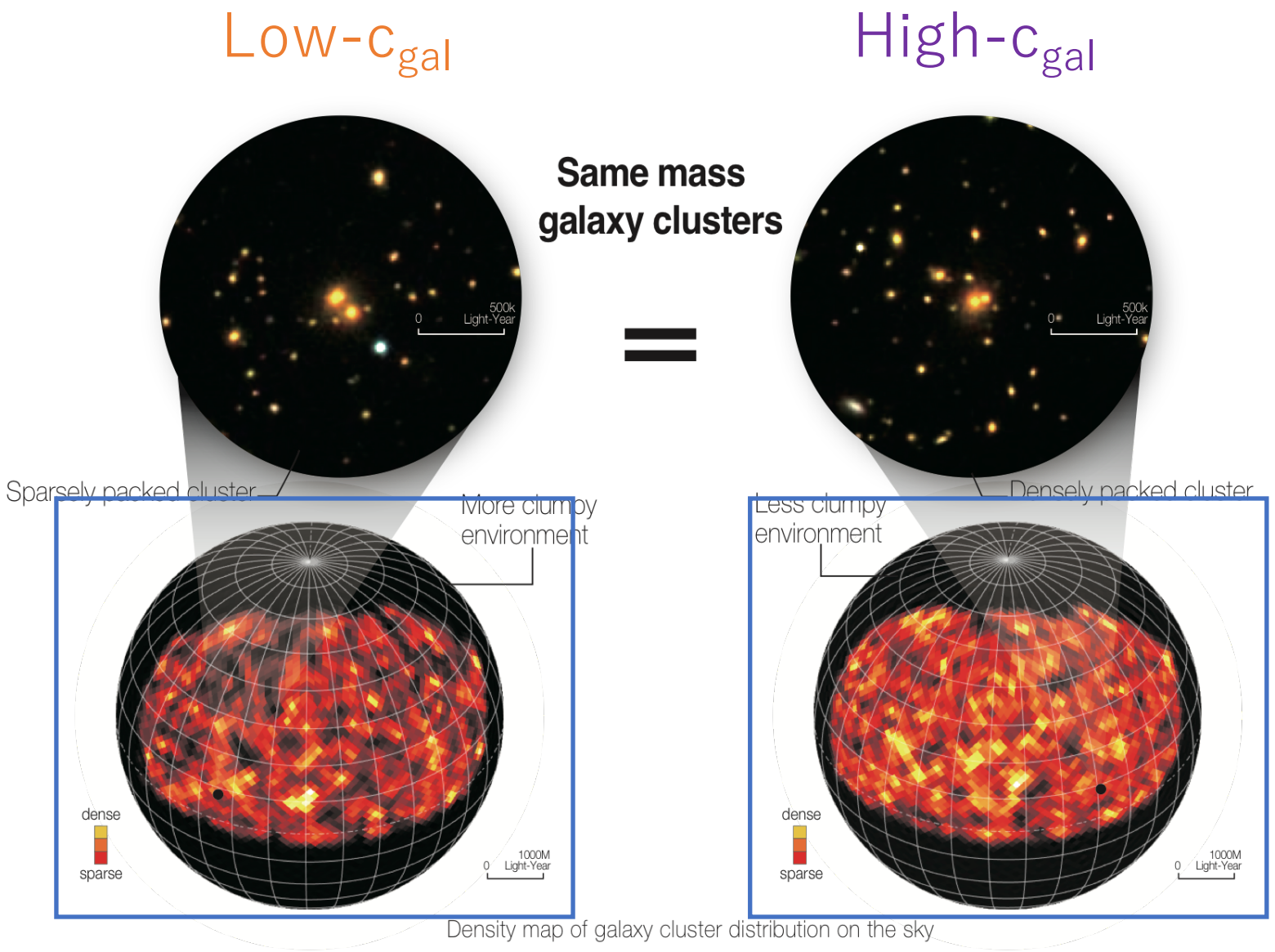


Image credit: NASA/ESA



Measurement

3. See if there is assembly bias by looking into difference in galaxy cluster distribution.



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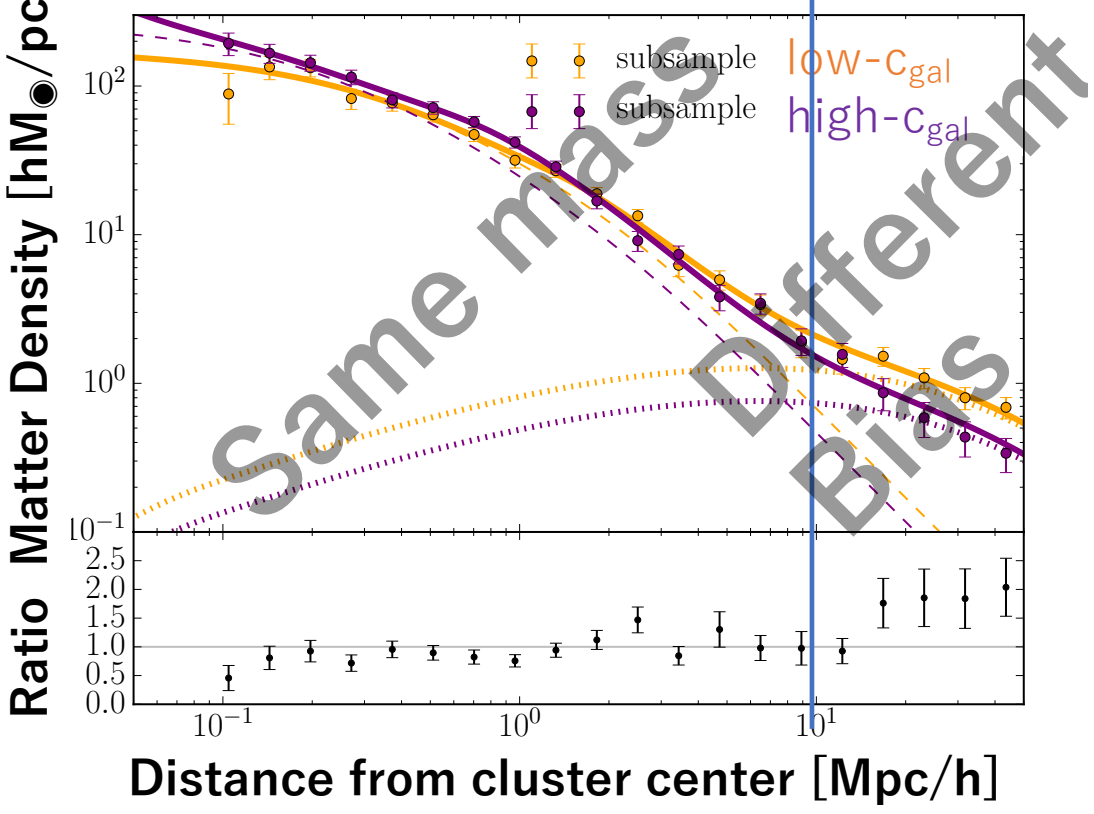
Results

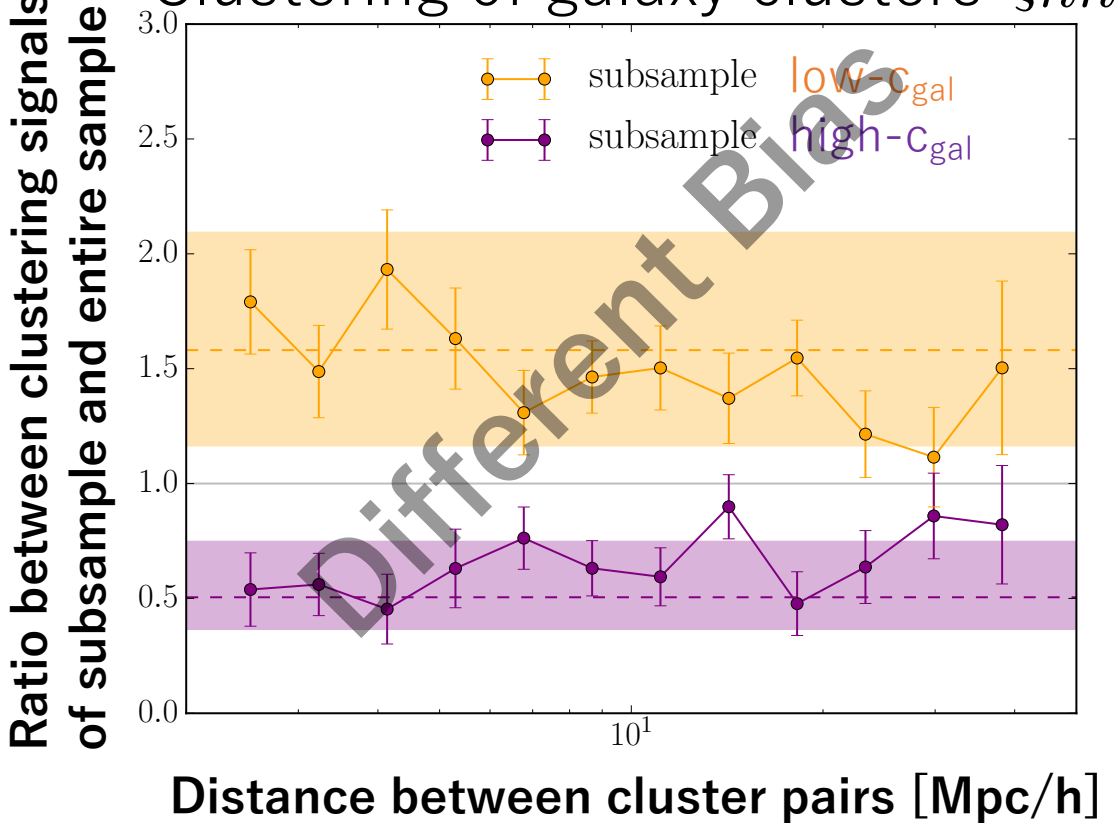
Inside of clusters | Neighboring clusters

Cluster Weak lensing



2.5 σ significance

Clustering of galaxy clusters ξ_{hh}



4.4 σ significance

Summary and Future Directions

- We found the first observational evidence of assembly bias
  - Selected cluster subsamples based on how member galaxies are concentrated.
  - Confirmed the subsamples have the same mass by weak lensing.
  - Found different bias in the subsamples by weak lensing and clustering.
- We need to do detailed systematic tests and comparisons with theoretical predictions. We need accurate simulations populated with galaxies.
- In the upcoming NASA's WFIRST survey, we need to take into account assembly bias when extracting dark sector information.