### Splashback radius: Observations and challenges

#### Surhud More

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### Edges of dark matter halos



How many moos in a given volume?

How are the moos distributed?



Springel et al. 2005

• Halo occupation distribution models need differentiation between the one and the two halo terms.

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### **Overdensity of FOF halos**



- can be understood using percolation theory
- not 180 for b=0.2
- depends upon concentration
- non-trivial but understandable dependence on the number of particles.

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SM, Kravtsov, Dalal et al. 2010

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Spherical overdensity halos: Suffer from pseudo-evolution (Diemer, SM, Kravtsov 2013)

### Edges of galaxy cluster halos



• A physical boundary that responds to the mass accretion history of the halo

Diemer and Kravtsov 2014 Adhikari and Dalal 2014 SM, Diemer and Kravtsov 2015

### Edges of galaxy cluster halos



#### iccretion

mer and Kravtsov 2014 hikari and Dalal 2014 , Diemer and Kravtsov 2015

# Early indications of splashback radius?



Number density of galaxies around Coma cluster

Splashback radius may not just be restricted to theoretical investigations

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# Early indications of splashback radius?



Splashback radius may not just be restricted to theoretical investigations

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#### Cluster-galaxy cross-correlation



 SDSS redMaPPer galaxy clusters cross-correlated with SDSS photometric galaxies

- Model with the 3d DK14 profile in order to infer the location of the steepest slope
- Observed location did not match predictions
  - Systematics (dynamical friction, background subtraction, miscentering, halo averaging effects, weak lensing mass estimation, magnification bias)
  - Projection effects in sample selection

Busch et al. 2017, Zu et al. 2017, Sunayama & SM 2019

Expanding the boundaries of dark matter halo

SM et al. 2016, Baxter et al. 2017, See also Chiang et al. 2018

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# Optical selection effects on splashback radius determination

 Cluster finding algorithms typically assign membership to galaxies based on a division between cluster member and a background.

$$p_{\text{mem}} = \frac{\lambda u(x|\lambda)}{\lambda u(x|\lambda) + b(x)}$$

- Background assessment
  - Global (redMaPPer, Rykoff et al. 2014)
  - Local (CAMIRA, Oguri et al. 2014)

### Systematics in modelling: assumption of spherical symmetry



See also: Sunayama 2023

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## What about local background subtraction?



- Mock cluster finder based on local
  background subtraction
  - The 20 percent or so reduction biases in the splashback radius reduce (perhaps in the opposite direction)

Murata, Oguri, SM, et al. 2020

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### **Edges of HSC CAMIRA clusters**



Murata, Oguri, SM, et al. 2020

 Subaru HSC allows us to access to deeper imaging and find clusters at higher redshifts

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### SZ galaxy clusters from Planck





#### About 13 percent statistical error

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Zuercher and More 2019 See also Shin et al. 2019, 2021

### SZ galaxy clusters





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#### X-ray galaxy clusters: RASS MCMF based on DECALS DR10





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Joshi, Rana, SM et al. (in prep) See also Divya Rana (talk tomorrow)

#### X-ray galaxy clusters: RASS MCMF based on DECALS DR10



- About 140 galaxy clusters selected based on X-ray luminosities
- Well measured weak lensing signal give masses
- The galaxy crosscorrelations show a splashback radius consistent with expectations.
- An 18 percent statistical error

Joshi, Rana, SM et al. (in prep) See also Divya Rana (talk tomorrow)

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### Accretion rates inferred from current measurements



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Joshi, Rana, SM et al. (in prep) See also Divya Rana (talk tomorrow)

## Satellite galaxies in galaxy clusters: orphan galaxy fractions



- Evidence of stripping in the inner halo regions
- Implications for upper limits on the orphan fractions

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Kumar, SM, Rana (2022) Kumar, SM, Sunayama (2024) Kumar & SM (2025, in review)

### Wishlist and Challenges

### Measurements of the splashback radius

- at few percent precision
- cluster selection separate from galaxies used to measure cross-correlations
- using features also in redshift space
- Constrain average mass accretion histories
  - Glean cosmological information
  - Use to understand what galaxy properties are correlated with accretion rates

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- Measurements of the splashback radius
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• Samples

 Obtaining large X-ray/SZ selected samples, tagged with different properties

• Tracers

- Galaxies (deep enough to avoid dynamical friction effects)
- ideally matter through weak lensing

Thank you!!!