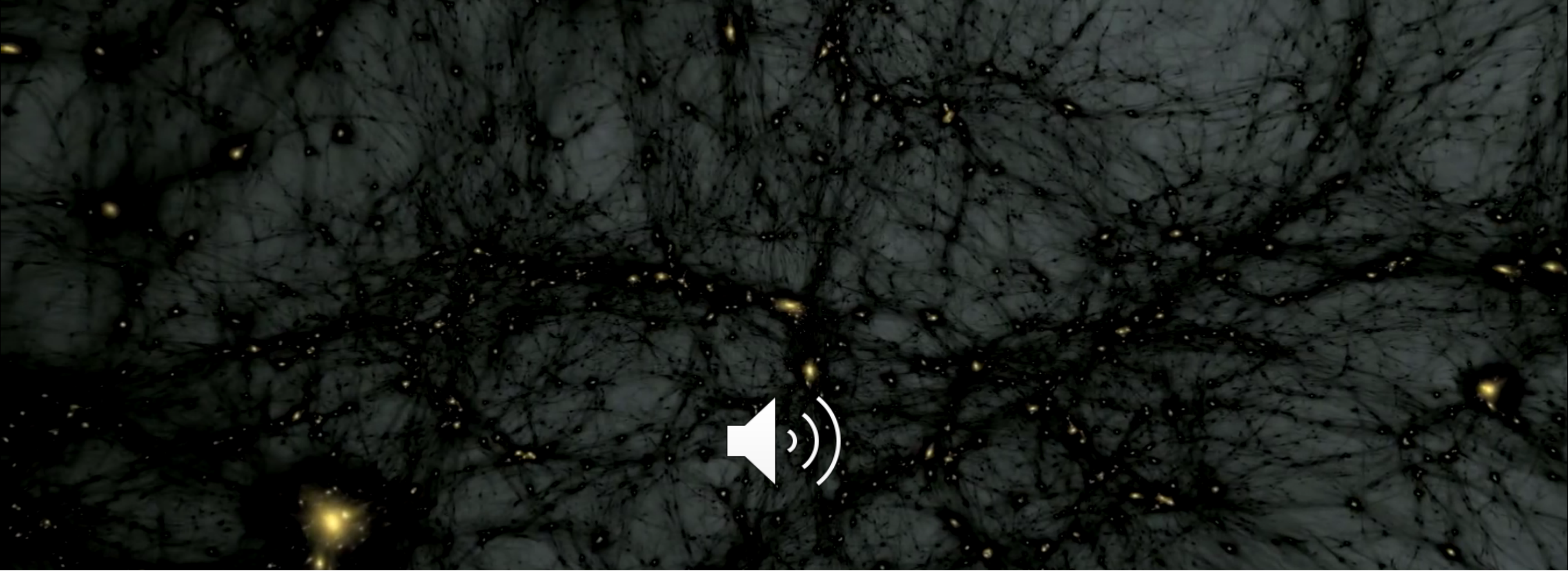

Virtual Research Presentation Conference

Mass and Motion, Tension and Concordance:
What are tensions in current data telling us about dark energy?

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Program: Strategic Initiative

Jet Propulsion Laboratory
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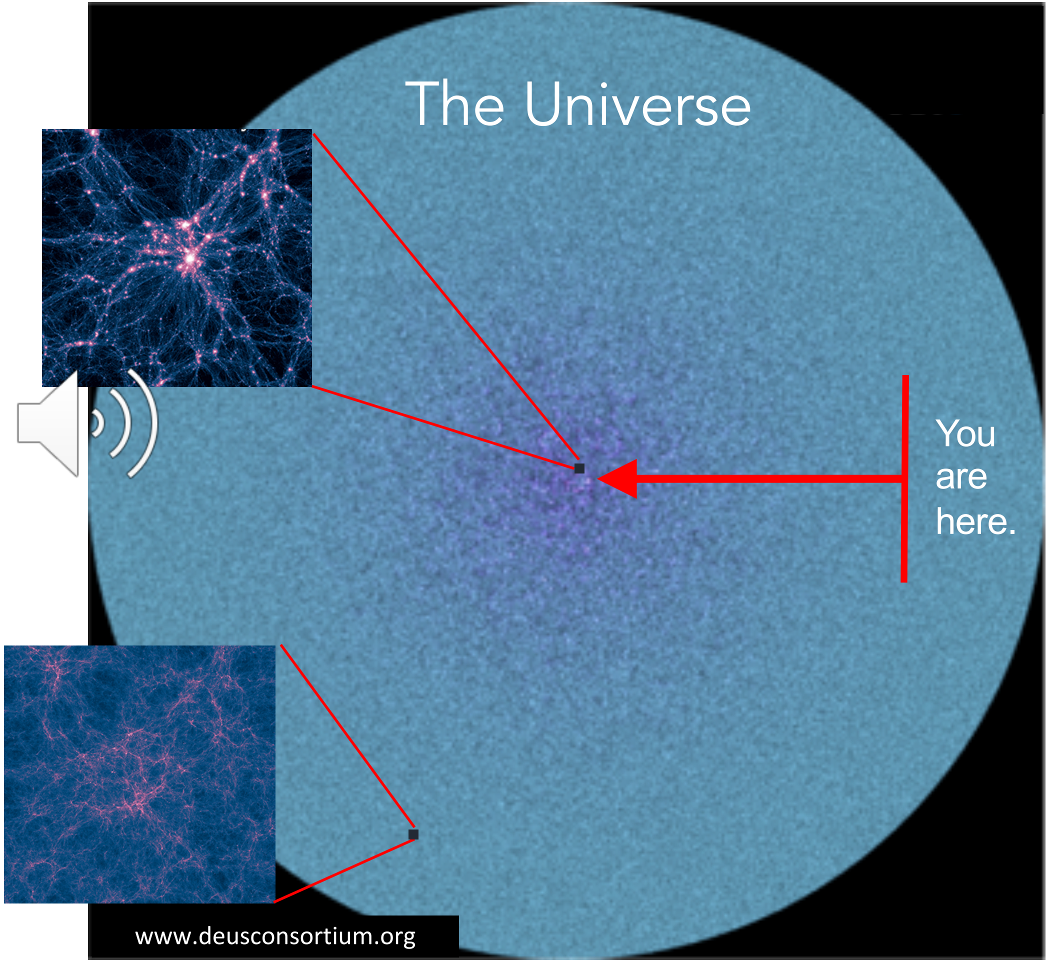
Introduction

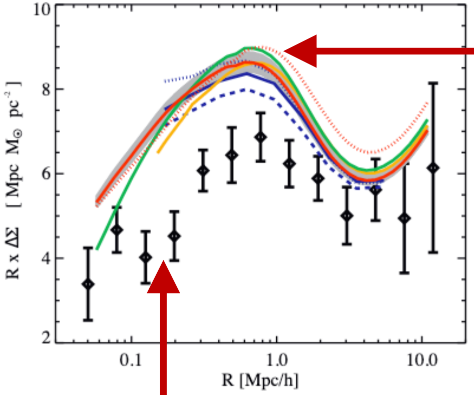
The accelerated expansion of the Universe is one of the most profound mysteries in all of physics. Understanding the dark energy responsible for this is a major focus of several ongoing large programs, as well as the primary science driver for the Roman and Euclid space missions.

The properties of dark energy are constrained in three ways:
1) observations of the primordial Universe (the Cosmic Microwave Background, or CMB)
2) measurements of the expansion rate of the Universe
3) maps of the Large-Scale Structure of the Universe, using *gravitational lensing* and *galaxy clustering*.

There are conflicts between results from each of these three probes. We do not know if this is due to unexpected properties of dark energy, or systematic biases in our experimental results. The purpose of this effort is **to find the source of these tensions**.



Cosmological Tensions:



Galaxy clustering measurements

Gravitational lensing measurements

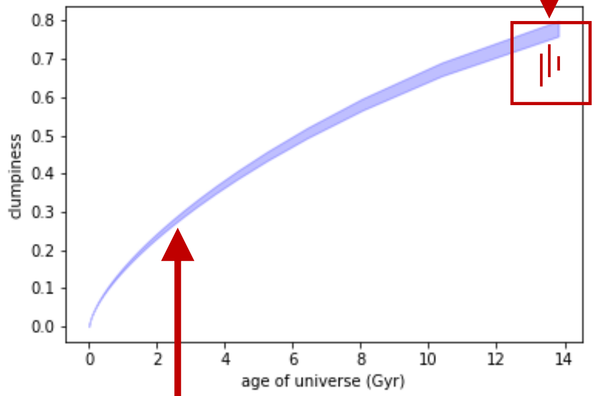
Weak gravitational lensing (WL) is a key probe driving Roman, Euclid, and several other missions JPL is involved in.

Recent WL measurements are not consistent with other probes of large-scale structure.

To find the source of this disagreement, we need **to compare simultaneous probes of the same dark matter structures**: galaxy motions and WL.

The models for motion and mass are not compatible at scales where most of the signal is. So we set about improving them.

Gravitational lensing measurements (late Universe)



Extrapolation from CMB measurements (early Universe)

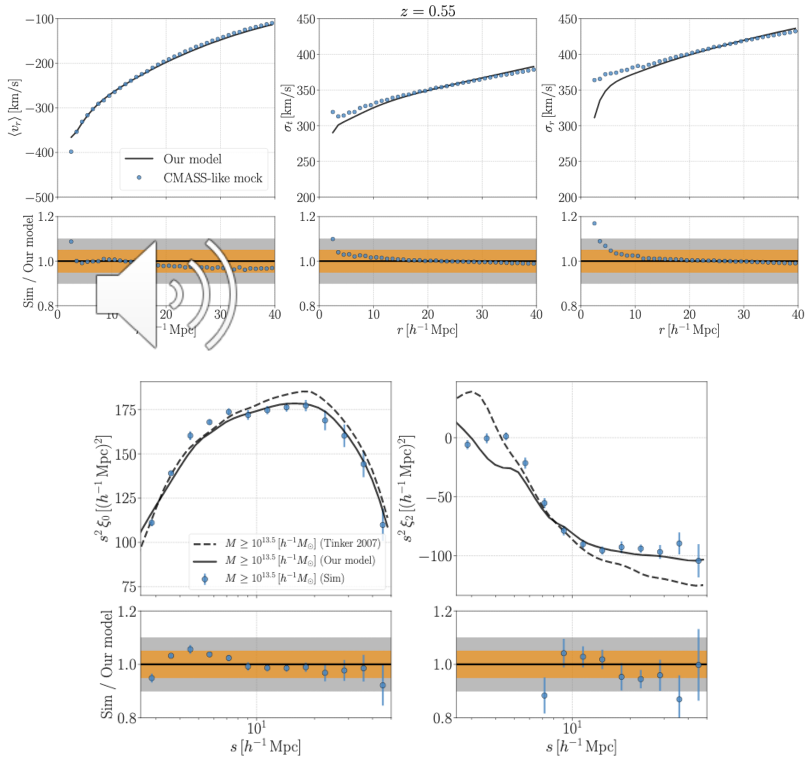
Redshift-space distortion modeling

Shirasaki, Huff, and Markovič developed a detailed model relating the velocities and masses of dark matter and galaxies (**right, top**).

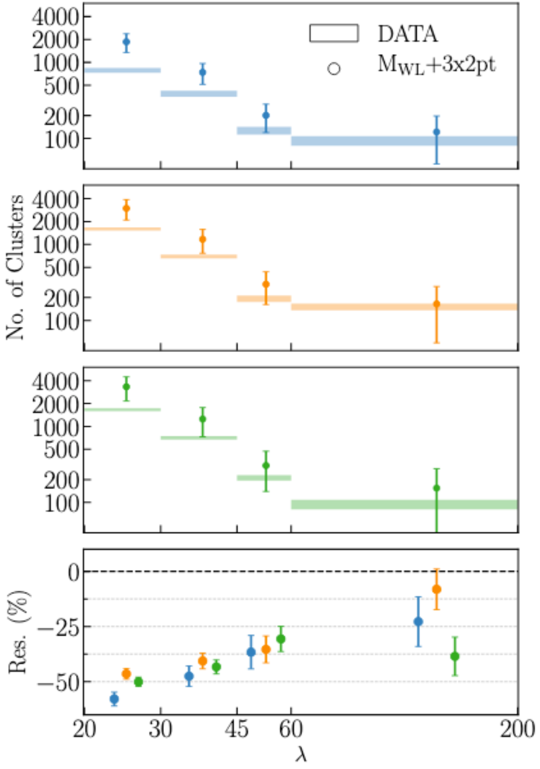
This improves our ability to model the RSD signal in simulations. **The improvement relative to state of the art is shown in the bottom panel at right**.

This model depends on the same underlying parameters as WL models, allowing future analyses to directly compare these two probes.

Our paper describing theses results was submitted to ApJ earlier this year [A].



Detailed investigation of galaxy clusters



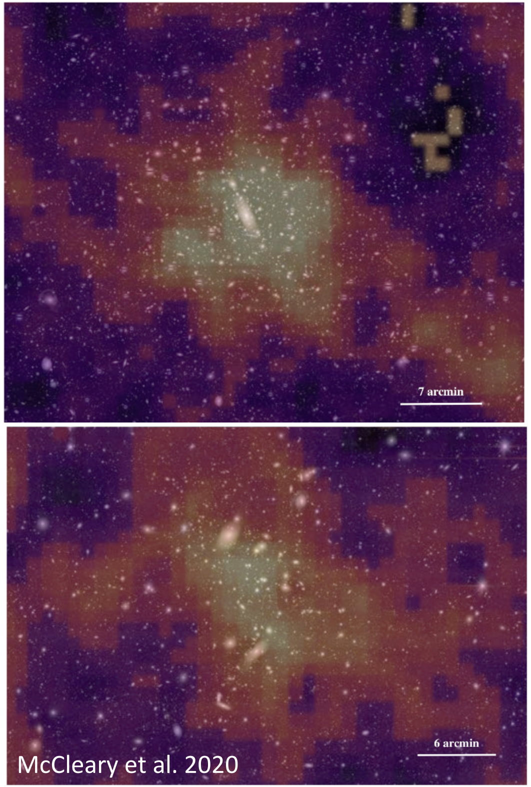
The abundance of galaxy clusters of different masses is also highly sensitive to the properties of dark energy.

Weak lensing is used to obtain masses.

The best recent cosmological constraints fand far too few clusters to be compatible concordance cosmology (**left**).

To investigate the source of this discrepancy, we have obtained and published [G] detailed mass maps of several massive clusters (**right panel**).

These will be a key ingredient in future analyses to better understand this tension.



McCleary et al. 2020

Publications

[A] **Shirasaki**, **Huff**, **Markovic**, & Rhodes (2020), *A semi-analytic model of pairwise velocity distribution between dark matter halos*, arXiv e-prints, arXiv:2008.02960

[B] Yahia-Cherif et al. (2020), *Validating the Fisher approach for stage IV spectroscopic surveys*, arXiv e-prints,arXiv:2007.01812

[C] d'Amico et al. (2020), *The cosmological analysis of the SDSS/BOSS data from the Effective Field Theory of Large-Scale Structure*, Journal of Cosmology and Astroparticle Physics, 2020, 005.

[D] Bose, Pourtsidou, **Markovič**, & Beutler (2020), *Assessing non-linear models for galaxy clustering - II. Model validation and forecasts for Stage IV surveys*, Monthly Notices of the Royal Astronomical Society, 493, 5301.

[E] Thomas, Kopp, & Markovič (2019), *Using large-scale structure data and a halo model to constrain generalized dark matter*, Monthly Notices of the Royal Astronomical Society, 490, 813

[F] **Markovic**, Bose, & Pourtsidou (2019), *Assessing non-linear models for galaxy clustering I: unbiased growth forecasts from multipole expansion*, The Open Journal of Astrophysics, 2, 13.

[G] **McCleary, J.**, dell'Antonio, I., and von der Linden, A., *Dark Matter Distribution of Four Low-z Clusters of Galaxies*, The Astrophysical Journal, vol. 893, no. 1. 2020

[H] Lee, S., **Huff, E. M.** et al. *Producing a BOSS CMASS sample with DES imaging*, Monthly Notices of the Royal Astronomical Society, vol. 489, no. 2. pp. 2887–2906, 2019.