National Aeronautics and Space Administration

FY24 Strategic Initiatives Research and Technology Development (SRTD)

Future of dark sector cosmology: systematic effects and joint analysis

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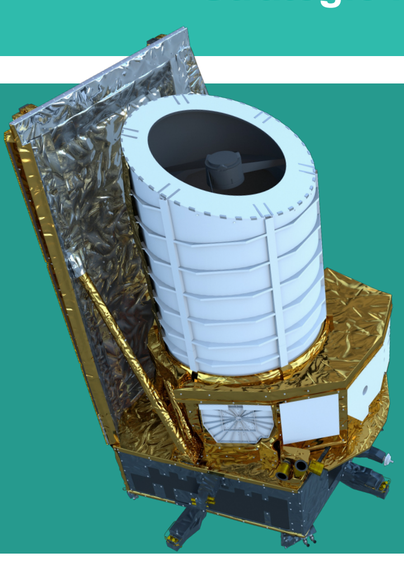
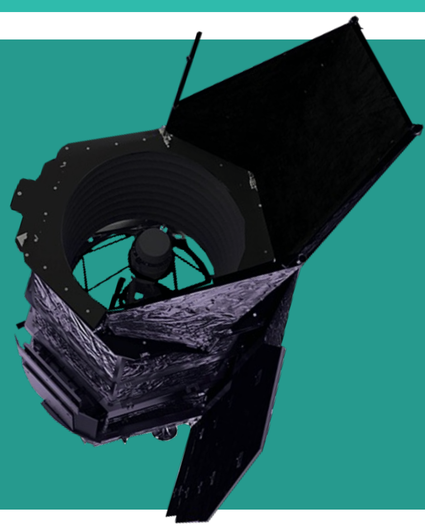
Strategic Focus Area: Developing Tools for Scientific Optimization of Missions | **Strategic Initiative Leader:** Charles Lawrence



To believe any tensions between early and late universe as coming from new physics, which would be a Nobel-Prize-level discovery, we need to have strong systematics control that matches the rigor of early universe analysis.

The forthcoming availability of the spectroscopic data from DESI, PFS, Euclid and Roman, along with the early science data from Rubin, makes this an ideal time to develop methods for combining the 2D and 3D survey programs. Our tools are going to help attain the needed systematic control by addressing individual probes, but more importantly, they will enable us to maximize the systematic control from joint analysis. Leveraging our involvement and recent advances will allow JPL to play a leading role in the large community endeavor to understand the nature of the dark Universe, and in preparing for and shaping what comes next.



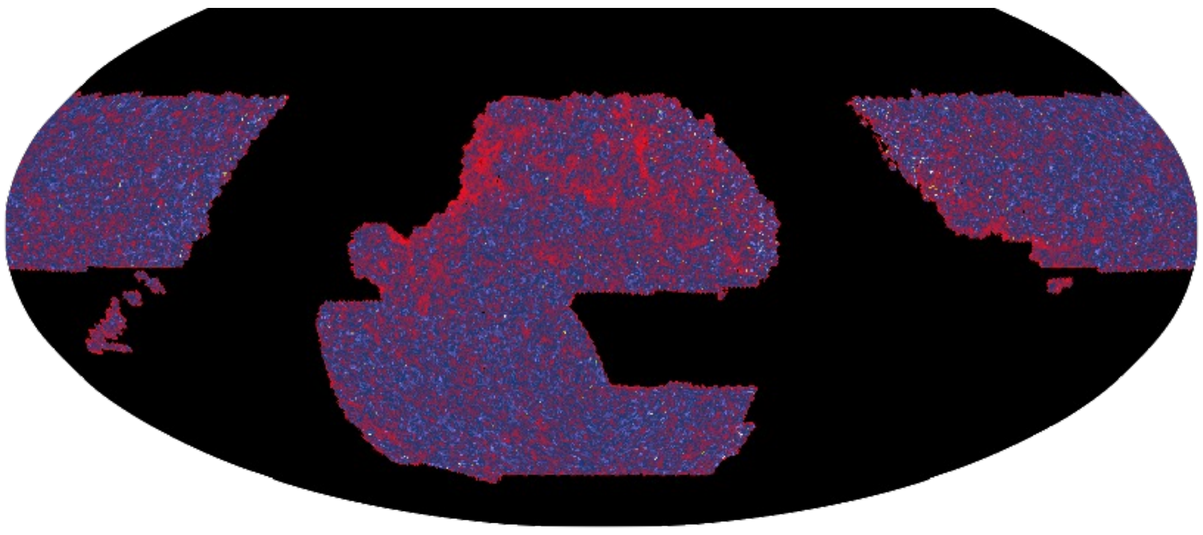
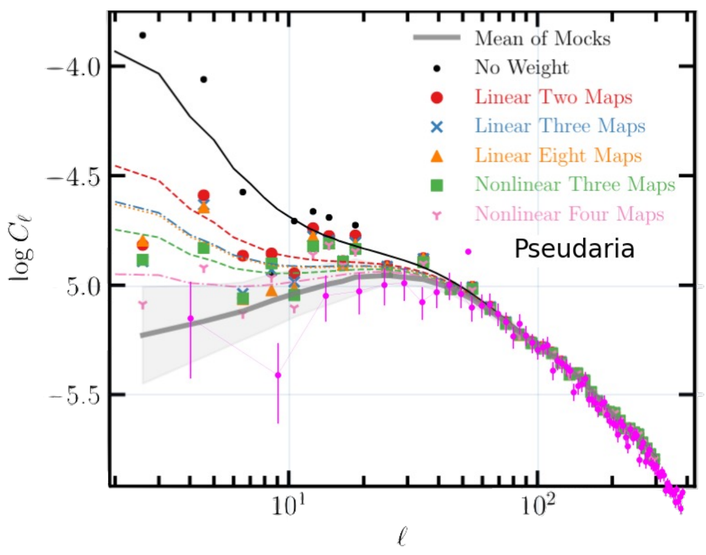


Figure 1: Pseudaria-derived map of systematic errors in the DECaLS data when compared to a reference map from Gaia quasars (Quaia").

During FY24, most of the work on **Objective 1** was to further develop and test Pseudaria. Pseudaria is a new method that, by using a quasi-Gibbs sampling of constrained realizations of systematics maps from two overlapping surveys, is able to quantify **unknown systematic errors**.

Figure 2: Pseudaria-corrected cosmological signal (pink), in concordance with mocks with no fNL. The other dots correspond to several models of known systematics (Rezaie et al, 2024).



We worked on applying Pseudaria to the public dataset from the DESI photometric precursor catalogs. Recent work has found a startling large value for the fNL measure of primordial non-gaussianities in this data. This case offers a real data test of Pseudaria if we can provide measurement of the systematic errors in an independent manner.

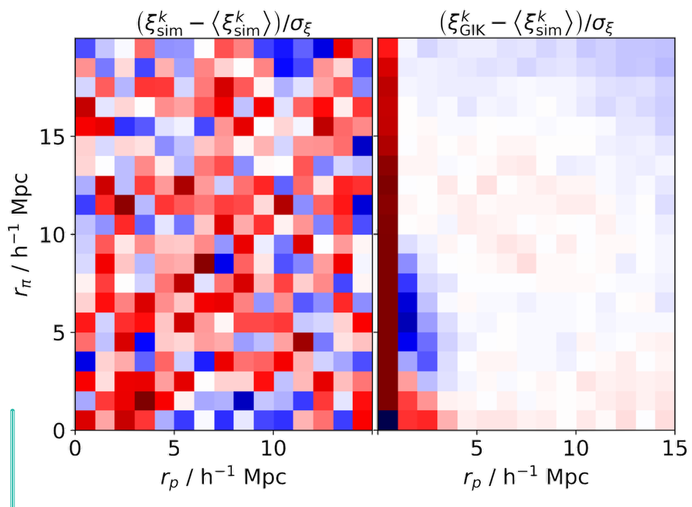


Figure 3: Maps of the difference between the "true" (simulated) redshift-space correlation function, and models. The right panel shows our model, while the left panel shows the leading alternative. Our model drastically reduces the noise in the model prediction, at the cost of small radii. [A]

An emulator for the pairwise velocity distribution of galaxies around galaxy clusters, was completed towards **Objective 2**. This emulator predicts how the cluster–galaxy velocity distribution depends on cosmological parameters and modifications to General Relativity theory. This was combined with knowledge of the real space cluster-galaxy cross-correlation, to build a model for the redshift-space cluster-galaxy cross-correlation, which can be directly measured from spectroscopic observations.

Towards **Objective 3**, we have been leading the efforts to obtain final results from the joint analysis of galaxy clustering and weak lensing measurements of the Dark Energy Survey (DES) for beyond-ΛCDM cosmologies such as dynamic dark energy, modified gravity, curved space, and massive neutrinos. [A] & [B]

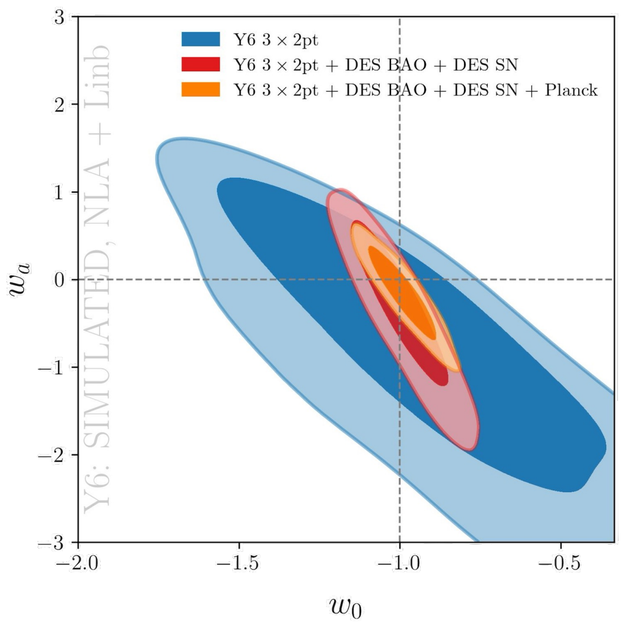


Figure 4: Dynamical dark Energy forecast for Dark energy Survey – Year 6 (final).

This year we made significant strides on all three fronts: systematics mitigation (O1), modeling (O2) and final joint analysis (O3). If successful after our final year, we will be in a strong position in the cosmology community, having demonstrated JPL's joint cosmological analysis capability to analyse the datasets of the upcoming large-scale structure data deluge, which we have been preparing for at least since the strategic grant from 2017, and which, with last year's launch of Euclid, is finally upon us. Further along the line, the nature and scientific desirability of any successor missions is likely to be determined by the results of science from the Roman/Euclid/Rubin/DESI era.

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Publications:

[A] DES Collaboration, "Dark Energy Survey: A 2.1% measurement of the angular baryonic acoustic oscillation scale at redshift zeff = 0.85 from the final dataset", PRD, v.110, n.6, Art. no. 063515, APS, 2024.

[B] Mena-Fernandez, J. et al., "Dark Energy Survey: Galaxy sample for the baryonic acoustic oscillation measurement from the final dataset", PRD, v.110, n.6, Art. no. 063514, APS, 2024.

[C] Robertson, Huff, Markovic, Baojiu, "Modelling the redshift-space cluster-galaxy correlation function on Mpc scales with emulation of the pairwise velocity distribution", MNRAS, V533, Issue 4, pp.4081-4103.

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