National Aeronautics and Space Administration

FY25 Strategic University Research Partnership (SURP)

Transforming cosmological discovery through joint analysis of ground- and space-based imaging

Principal Investigator: Jason Rhodes (5300)**; Co-Investigators:** Eric Huff (322), Rachel Mandelbaum (CMU), Federico Berlfein (CMU), Axel Guinot (CMU), Andy Park (CMU)

Objectives

Our overall objective is to develop a pipeline to constrain cosmological parameters combining calibrated images from the ESA's Euclid space telescope and the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST). The first step (year 1) was to make software that can be used to generate joint simulations of images from Euclid and LSST surveys. In year 2, we have done further development and validation towards a full production run. In year 3, we will use these simulations to validate our analysis pipeline and quantify the gains in reducing statistical uncertainties in the cosmology constraints by combining the two surveys.

Approach and results

FY25 has been focused on finishing the development of the simulation software and running validation tests.

The code is now finalized and publicly available on GitHub: https://github.com/GalSim-developers/GalSim-Euclid-Like. We have simulated 1 deg2 of Euclid-like images (9 tiles) that we have used to make a series of tests. We have performed comparison and validations of our simulations. Earlier this year was the first EUclid public data release and now that we also have real observations we can also investigate the discrepancies between the observed galaxy morphology and our input catalogue. We will use those results to further improve the input cosmology catalogue which will also be useful for other surveys to provide more realistic galaxy distributions. This is particularly important for cosmic shear, which is at the center of all the collaborations that use this catalogue.

We now have all the tools to make simulations across three Stage-IV surveys: LSST, Roman, and now Euclid. We are looking toward a production run by the end of 2025. The rest of the coming year will be focused on doing joint analysis with LSST to investigate the gain we would get on cosmology. The most likely improvement will come from a better understanding of blended galaxies on LSST images by using the better resolved Euclid-like simulations and that will be our main focus.

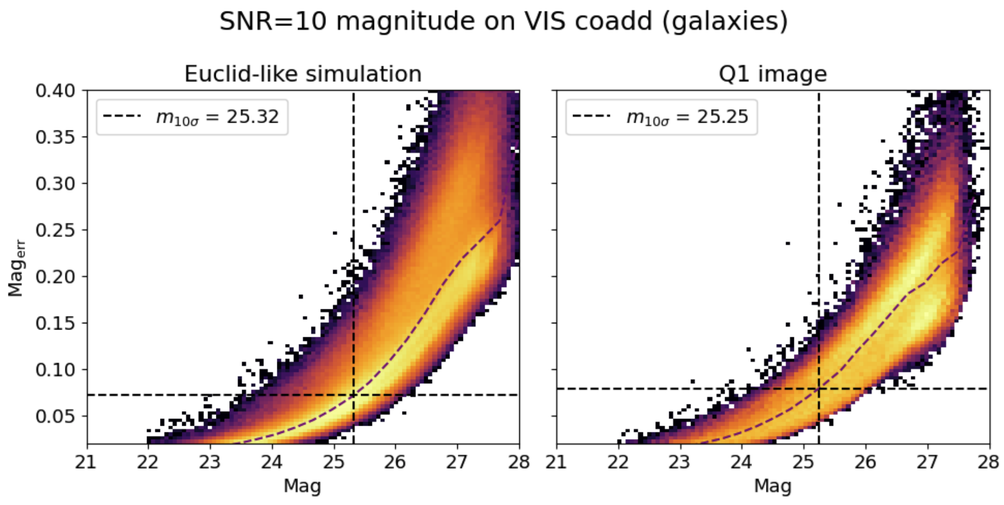

Figure 1. This figure shows a comparison of the depth of a simulated Euclid-like coadded image (left) and a real Euclid coadd (right). We can see that the distribution and 10σ depth of the simulated image is very close to the real observation.

Background

Weak gravitational lensing refers to the light from background galaxies being deflected by the inhomogeneous foreground matter distribution, leaving small but coherent shear distortions on background galaxy images. Since the shear distortion is related to the projected matter (including dark matter) fluctuation along the line-of-sight, weak lensing can be used to probe the statistical distribution of dark and luminous matter in the universe and its redshift evolution, and thereby constrain the cosmological parameters. To be more specific, one can measure the shear distortions from images of background galaxies to obtain a catalog of shear distortions. Such a catalog allows measurement of cosmological parameters, e.g., the total matter density and the standard deviation of the matter fluctuations.

Recent studies focus on developing pipelines for joint cosmology constraints using catalogs from current weak lensing surveys. However, compared to jointly estimating shear and combining the signal from different surveys at image level, the caveat of the catalog-level joint analyses is the difficulty in accurately quantifying the covariance between two surveys overlapping the same region on the sky. Future surveys will benefit from joint shear analysis if we develop a joint shear estimation pipeline that accurately measures the covariance of the measurements.

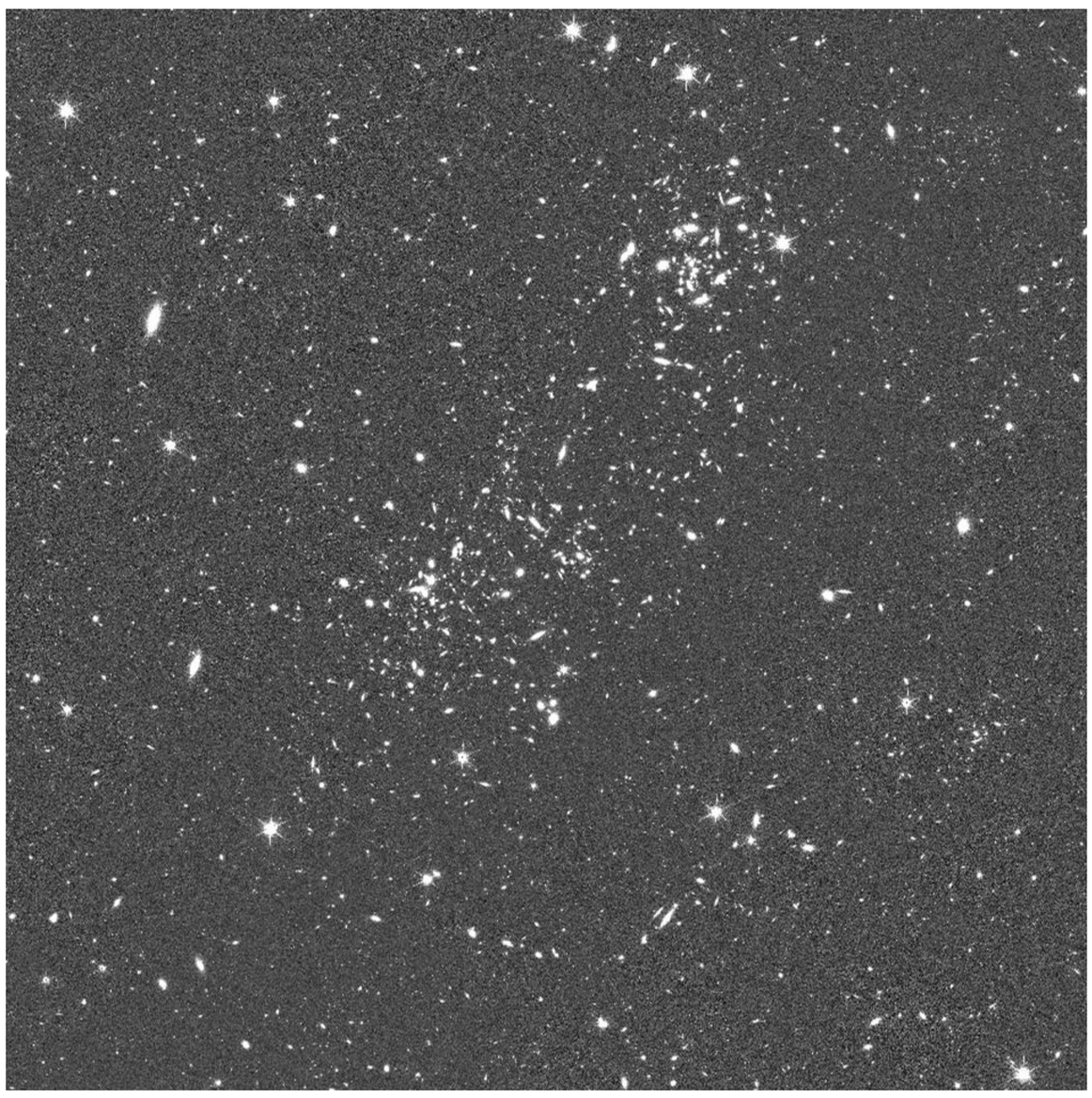

Figure 2. Simulated Euclid-like coadded image.

Significance/Benefits to JPL and NASA

With the release of a large batch of Euclid data expected at the end of 2026 and the start of full operations for Rubin in the coming year, the time is right to develop plans for a joint analysis of these data sets. This is beyond the scope of either Euclid or Rubin, and this effort will position CMU and JPL at the forefront of the joint analysis effort. When Roman data start becoming available in 2027 they can be folded in as well.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

RPD-36Clearance Number: CL#25-4029

PI/Task Mgr. Contact Information:
Jason.d.Rhodes@jpl.nasa.gov 626-31807165