**Euclid General Investigator Program**
**Abstracts of selected proposals**
**NNH24ZDA001N-EGIP**

Below are the abstracts of proposals selected for funding for the Euclid General Investigator Program. Principal Investigator (PI) name, institution, and proposal title are also included. 37 proposals were received in response to this opportunity. On January 24, 2025, 14 proposals were selected for funding.

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**24-EGIP24-0012 –** Dependence of Weak Lensing Cluster Mass Calibration and Systematics on Cosmology

**PI:** Camille Avestruz
**Institution:** University of Michigan, Ann Arbor

**Summary:**
Euclid was designed to enable cosmological studies on the dynamic nature of dark energy and on the growth parameter with two primary probes in mind: galaxy clustering and cosmic shear. The addition of another cosmological probe, the cluster number counts, will provide a definitive answer to current debates on the Hubble parameter and on the universe homogeneity, measured with the S_8 parameter. The number count statistics, representing the distribution of the cluster masses over redshift, will be built with weak-lensing derived masses which, however, are affected by biases. Sources of bias are associated with the incoming signal, the modeling of the lens, and the intrinsic properties of the lens. This proposal will focus on the second and third categories, since the first has been deeply studied by the Euclid collaboration.

Biases linked to the gravitational lens, i.e. to the cluster, have been investigated in literature using numerical simulations which allow a quantitative comparison between the halo true mass and the weak-lensing derived mass. The most accurate work is based on hydro-simulations: the gas is a fundamental component for calibration studies since for more than one decade it has been demonstrated that baryons have a lasting effect on cosmological measurements with the mass function. None of the past investigations, however, looked at the cosmological dependence of the weak-lensing mass bias and of its scatter.

We propose to utilize a recently completed simulation suite of two hydro-dynamical cosmological boxes (one characterized by a large volume, ~900 Mpc/h, the other by a 20X better mass resolution, m_DM ~7e8 Msun/h) carried out 15 times, each with a different combination of four key cosmological parameters: the cosmic matter and baryon densities, the Hubble parameter, and sigma8. Using this rich simulation suite, we will provide cosmology-parametrized functions for the following WL systematic bias sources: (1) in relation to the cluster modeling: the halo concentration, the truncation radius, which describes the transition in the density profile between the cluster main term and the large-scale-structure in form of both correlated and uncorrelated matter, and the projected surface density contribution of this second halo term; (2) in relation to the intrinsic properties of clusters: the dynamical state and the triaxial shapes. The final deliverables of this work will be four papers, catalogs of these measurements, and the cosmology-parametrized functions for the WL systematics.

In parallel, we will produce synthetic Euclid-like observations of the simulated galaxy clusters that will be analyzed with an observational-like pipeline. The resulting paper will include a comprehensive interpretation of all the previous results on the lens modeling and intrinsic properties whose robustness will be checked against the more realistic case of mock observations and observational analysis.

Concluding, to significantly reduce the uncertainties on cosmological parameters, the systematic biases need to be small to not overwhelm the order of magnitude increase in statistics that Euclid will provide. Biases, which are irreducible, will need to be accurately modeled to be folded in the full Bayesian cosmological analysis. This project will provide this fundamental piece of information in relation to weak-lensing mass biases due to the cluster's modeling and the cluster's intrinsic properties. This project is thus directly responding to the NASA EGIP call, which aims to support ""theoretical investigations that will advance the science return of the Euclid mission"". Our results also address the aims of NASA's Astrophysics Division whose purpose includes exploring ""the behavior of matter and energy in extreme environments"", ""the cosmological parameters governing inflation and the evolution of the universe"", and ""the nature of dark matter and dark energy"".

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**24-EGIP24-0021 –** Exploring uncharted corners of the solar system with Euclid to inform planetary formation models
**PI:** Artem Burdanov
**Institution:** Massachusetts Institute of Technology

**Summary:**
Despite being designed to study dark energy and dark matter, the ESA Euclid mission offers the unprecedented opportunity to address the question ""How did the giant planets gravitationally interact with each other, the protosolar disk, and smaller bodies in the solar system?"", prioritized in the 2023-2032 Planetary Decadal Survey. Indeed, the mission is guaranteed to significantly expand the inventory of Solar System Objects (SSOs), discovering ~150,000 new SSOs with highly tilted orbits mainly from the Euclid Wide Survey. SSOs are widely thought to be the leftovers of planet formation. Therefore, measuring their orbital and physical properties provides key clues to how the solar system formed.

Our proposal to the NASA Euclid General Investigator Program aims to detect new (esp. highly-inclined) TNOs  in all non-Wide Survey data using the GPU-based synthetic tracking (shift-and-stack) technique. We will be sensitive to SSOs with magnitudes down to ~V_AB=27--30 at an SNR of 5 in data collected by the VISible imaging camera (VIS). In Deep Field and calibration images, we expect to detect between O(1,000) and O(10,000) highly-inclined TNOs (O = order of). The lower value of the expected yield above refers to the scenario of a mostly-planar distribution as currently observed, which is likely affected by the observational bias of most observations being performed in the ecliptic plane. The higher value assumes a uniform inclination distribution. The expected range of detections would constitute an increase between

+25% and +250% in terms of known TNOs with respect to the current census, and >+20% increase with respect to the Euclid TNO detection yield calculated assuming more standard (i.e., non-shift-and-stack) data analysis techniques.

Our survey is most sensitive to discovering small/distant and/or highly inclined TNOs, although it will also perform a deep search in a couple of low-inclination fields, which we will use as references to anchor our population study. The orbits and colors of these objects hold clues to the formation and evolution of the solar system, enabling us to address key questions about how the outskirts of the solar system evolved. Probing new corners of the {size, inclination, colors}-space is key to constrain the mass-transfer process beyond the global TNO population which recorded the evolution of the giant planets.

Our proposed legacy science investigation is in scope of the NASA Euclid General Investigator Program Euclid because it aims to discover new SSOs and advance planet formation theory by making ""broad scientific utilization of the mission [...] using Euclid data"". Importantly, the proposed investigation complements, but does not duplicate, the activities of the Euclid SSO working group of detecting moving objects as faint as visible magnitude V_AB=24.5 using single images and linking their motion across images from a single Euclid tile. This approach is expected to miss the detection of faint (V_AB>24.5) SSOs that are not visible in individual images. Our proposed investigation focuses on easing this limitation. Moreover, it will inform possible strategies for leveraging Euclid's amount of idle time, and its possible extended mission.

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**24-EGIP24-0017 –** Probing the High Redshift Universe as a Tracer of the Evolution of Dark Energy
**PI:** Andrew Connolly
**Institution:** University of Washington, Seattle

**Summary:**
Recent evidence from the Dark Energy Spectroscopic Instrument (DESI) and the Dark Energy Survey (DES) suggest that Dark Energy (DE) may not be, as long hypothesized, a cosmological constant, but rather a slowly evolving energy density. Further analyses from DESI, Euclid, and other upcoming experiments (e.g. Rubin LSST) will investigate whether this signal is real or a systematic error by probing large scale structure in the low-redshift universe where DE dominates the cosmic energy budget. To pin down the evolution of a slowly-evolving DE, however, it is important to probe cosmic structure across as large a range of redshifts as possible. A long redshift baseline provides strong leverage to distinguish between evolving and non-evolving DE models, and high redshifts are especially important as many competing theories for evolving DE make nearly identical predictions for the low-redshift universe but diverge at high-redshifts.

We propose using Euclid photometry to probe the growth of large-scale structure at redshifts $2 < z < 6$ in the matter-dominated era using Lyman-break galaxies (LBGs). The clustering and cross-correlation with CMB lensing of these galaxies will provide precision constraints on the density and evolution of DE. The combination of our high-redshift constraints with low-redshift Euclid constraints will improve the DE Figure of Merit by a factor of 6. If DE is a cosmological constant, the joint constraints should exclude the evolving DESI model at 3.5-sigma. If the evolving DESI model is correct, the joint constraints should exclude a cosmological constant at 11-sigma.

Euclid's deep visible band will be essential for detecting these high-redshift LBGs, providing photometry free from atmospheric turbulence, yielding a more uniform selection function and higher-resolution imaging with far less blending than ground-based surveys. Euclid's near-infrared photometry will significantly improve photometric redshifts (photo-z's) by localizing the Balmer break. Supplementing Euclid photometry with ground-based visible photometry will enable clean tomographic splitting of this sample by more precisely localizing the Lyman break.

The most important systematic error we must confront is sample redshift calibration. Traditional color-color cuts are suitable for selection and redshift tomography. Redshift calibration, however, is traditionally performed via collecting spectroscopic redshifts for a subsample of galaxies. This, however, will be insufficient for our work as sufficiently large and representative spectroscopic samples do not exist at these high redshifts. To address this problem, we will use a hybrid deep-learning model that combines template-based photo-z estimation with data-driven machine learning, using stellar synthesis models as a theoretical prior. We will also use this spectral model to measure the UV luminosity function of $2 < z < 6$ LBGs. These luminosity functions will be used to improve the high-redshift calibration of the cosmological simulations we will use to calibrate our galaxy bias model and other systematic errors for our DE analysis.

As a result of this project we will deliver a tomographic catalog of LBGs from redshifts $2 < z < 6$, algorithms, software, and a calibrated model for LBG photo-z estimation, UV luminosity functions, and constraints on the evolution of DE in the high-redshift universe, measured from the clustering and CMB lensing cross-correlation of LBGs detected with Euclid.

Through its study of the evolution of dark energy, this proposal aligns with NASA's strategic objective in astrophysics to understand the evolution of the universe through the ""Physics of the Cosmos"" and ""Cosmic Origins"" research themes. Our proposed framework is ideally suited for broad scientific utilization of publicly available Euclid data (Q1, DR1, Q2).

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**24-EGIP24-0018 –** Harnessing Galaxy Structure to Probe Galaxy Evolution in the Euclid Era

**PI:** Andrew Connolly
**Institution:** University of Washington, Seattle

**Summary:**

The structural parameters of galaxies serve as a cornerstone in comprehending their current state and evolutionary history. The intricate correlations between galaxy morphology and other physical properties of galaxies (e.g., star-formation rate, AGN activity) have played an instrumental role in furthering our understanding of galaxy formation and evolution. During the period of this solicitation, the Euclid Wide Survey will release imaging data over 2500 square degrees at near-Hubble spatial resolution. This unprecedented dataset will enable the measurement of galaxy structure for 0.5 billion galaxies out to $z\sim4$ and down to mag ~23.5.

While machine learning (ML) has gained popularity for studying galaxy morphology, most studies have produced broad, qualitative classifications (e.g., disk-dominated, presence of bars) rather than precise numerical estimates of structural parameters (e.g., radius, CAS parameters). Furthermore, both ML and non-ML tools have been shown to underestimate uncertainties severely. Accurate Bayesian posteriors for structural parameters of large samples is essential for:

a) determining robust scaling relations,
b) uncovering subtle correlations or hidden variables within strong correlations, and
c) tests of theoretical models using morphology.

We propose to fine-tune and apply two state-of-the-art Bayesian ML tools -- GaMPEN and PSFGAN -- to determine the structural parameters of the above-mentioned sample, covering both inactive galaxies and galaxies with active black holes (AGN). GaMPEN excels in estimating user-defined structural parameters for large datasets, producing posterior distributions with exceptional calibration (<5% deviation) and outperforming traditional light-profile fitting codes by up to 60%. PSFGAN complements GaMPEN by accurately subtracting central point sources, allowing GaMPEN to be applied to AGN host galaxies.

We will use the determined structural parameters to:-

i) Analyze the Correlation of Structural Parameters with Other Properties: Specifically, we will investigate how galaxy sizes and other parametric/non-parametric structural parameters vary with color, stellar mass, and environmental density. The large sample will enable us to explore correlations with unprecedented statistical significance over a range of galaxy mass previously unattainable. It will also allow us to identify rare objects (e.g., clumpy disks), helping the connection of galaxy morphology distributions to their evolutionary origins.

ii) Characterize Massive Spheroids: We will characterize the population of massive spheroids to high redshift. By measuring the surface brightness profiles of millions of ellipticals, we aim to determine whether any dense early ellipticals survive to the present day. This analysis will shed light on the roles of mergers and environmental effects in the evolution of spheroids, two processes that Euclid will uniquely characterize.

iii) Assess AGN Impact: We will measure the impact of AGN activity on galaxy morphology and structural parameters. We will also use the derived structural parameters as a proxy for merger history to robustly quantify the role played by galaxy mergers in triggering AGN. The nature of the sample will allow us to quantify these correlations over mass ranges and statistics previously unattainable.

This proposal aligns with NASA's strategic objective in astrophysics to understand the evolution of the Universe through the ""Cosmic Origins"" research theme. Our proposed framework will utilize publicly available Euclid data (Q1, DR1, Q2), while providing precious publicly-available ML models and morphology catalogs to the broader community. The tools developed will be critical not only for future Euclid data releases but also for maximizing the potential of the Roman Space Telescope, NASA's top priority for a new strategic astrophysics mission.

**24-EGIP24-0031 –** Blind to 100,000 Strong Lenses: Spectroscopic Analysis with SLETE, a Strong Lens Extraction Tool for Euclid
**PI:** Andreas Faisst
**Institution:** California Institute of Technology

**Summary:**
Euclid's unprecedented combination of area and depth yields enough statistics to study rare but important phenomena for the first time. To this category belong galaxy-galaxy strong lensing (SL) events, the by-chance chance alignment of a bright foreground galaxy (lens) with a faint background galaxy (source). The gravitational potential of the lens magnifies the source's flux by factors of several and distorts its image into an Einstein ring, arc, or multiple images. SL systems therefore provide unique laboratories to study galaxies near and far thanks to the magnification in brightness and resolution of source galaxies: they are the only way to directly study dark matter (DM) properties of individual galaxies, they enable the study of faint high-z galaxies (too small and faint without magnification), and place constrains on various cosmological parameters.

Euclid will discover more than 100,000 SL systems over the 15,000 square-degrees of its wide field survey with the VIS (visual) instrument. Spectroscopic measurements of lenses and sources are crucial for any study involving strong lenses. Euclid does perform near-IR spectroscopy with NISP over the same area, however, the complicated geometry of SL systems (blending, low source-lens contrast, Einstein rings and multiple source images) poses significant challenges to the standard slitless spectroscopy pipeline of Euclid. Most Einstein rings are smaller than ~0.7"", resulting in blending of source and lens at the NISP spatial resolution (0.3""/px), making Euclid spectroscopically blind to these systems. Dedicated methods therefore need to be applied for de-blending the photometry as well as the spectra of lens and source to push the frontiers of current research.

We propose to enhance the science output of the Euclid imaging and slitless grism survey through the spectroscopic analysis of SL systems to specifically deepen our understanding of the co-evolution of stellar and DM mass, characterize DM profile in massive galaxies, and reveal the population of strongly lensed high-redshift galaxies. Our proposed project over two years consists of two parts:

1. Develop the Strong Lens Extraction Tool for Euclid (SLETE) to overcome the limitations of the standard pipeline with a combination of machine learning and advanced source deblending to accurately measure the photometry and spectra of lens and source in SL systems

2. Apply SLETE to ~2000 square-degrees of public Euclid data (Q1, Q2, DR1) to measure the evolution of the stellar to DM mass ratio and DM halo profiles in 1000s of galaxies across 11 billion years of cosmic time out to z = 3.

The proposed project is highly relevant for the astronomical community as it uniquely enables photometric and spectroscopic measurement of SL systems in the Euclid data beyond the data

products delivered by the Euclid consortium. SLETE will be made available to the public to encourage the community to study many more science aspects related to SL systems over the full Euclid coverage, which are not covered by this program. The output of this project will be invaluable for the community in pursuing these studies with Euclid. It is therefore of significant importance for NASA's scientific interests in astrophysics and cosmology.

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**24-EGIP24-0036 –** Unveiling the Nuclear Regions of Nearby Galaxies and AGN: Harnessing Euclid's Superior PSF and Wide-Field Coverage
**PI:** Michael Koss
**Institution:** Eureka Scientific, INC.

**Summary:**
Understanding the nuclear regions of galaxies is crucial to unravel the processes of active galactic nucleus (AGN) fueling and feedback and their connection to galaxy evolution. The interplay between supermassive black holes (SMBHs) and their host galaxies is influenced by nuclear star formation, bars, spirals, dust lanes, and potential hidden mergers. However, previous studies have been limited to small samples, making it difficult to reach a consensus on the mechanisms driving SMBH accretion.

We propose a comprehensive study of the optical nuclear morphologies of a large sample (N~1000) of nearby (z<0.1) galaxies with publicly available HST or Euclid Q1 data, leveraging Euclid's wide-field coverage and superior PSF, alongside archival HST imaging study of 506 of the brightest luminous AGN in the sky from the Swift BAT AGN Spectroscopic Survey (BASS). Euclid's Q1 data will provide imaging of ~500 nearby inactive galaxies, enabling detailed morphological comparisons between AGN and inactive galaxies. This will be achieved through human classification on Zooniverse and state-of-the-art machine learning techniques.

Our goals include:

1. Characterizing nuclear structures (spirals, bars, dust, hidden mergers) in AGN compared to inactive galaxies.
2. Identifying processes uniquely associated with AGN fueling and SMBH growth as compared inactive galaxies.
3. Investigating the correlation between AGN obscuration and nuclear morphology.
4. Develop the framework to rapidly expand these techniques for the DR1 and later releases which will have more than 20,000 nearby galaxies.

We will employ a full-time early career postdoc to lead the classification of nuclear morphologies using Euclid and HST datasets, applying ML tools like Zoobot for efficient analysis of large datasets. By focusing on sub-kpc scales, this study will provide key insights into the gas inflow mechanisms that fuel AGN, the impact of dust lanes and mergers, and the role of AGN feedback in shaping nuclear regions.

This project aligns with the overarching science goals of the Euclid mission and NASA's objectives to explore the physics of the cosmos, including the nature of black holes and galaxy

evolution. By combining extensive wide-field data from Euclid, we will explore the small-scale nuclear processes that drive galaxy evolution and connect them to larger-scale structures in the universe that is complementary to the small field of view studies with HST and JWST. This first-of-its-kind large-scale nuclear morphological study will not only uncover hidden processes shaping galaxy nuclei but will also provide critical benchmarks for studying SMBH growth and AGN feedback.

Through this proposal, we aim to advance open science by releasing data, software, and ML tools to the scientific community, fostering collaboration and broadening the impact of the Euclid mission. We also plan to establish a Zooniverse citizen science project to engage the public in nuclear morphological classification, inspiring the next generation of scientists through direct participation in astrophysical research.

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**24-EGIP24-0006 –** Illuminating Cosmic Reionization: Direct Measurement of the Ionizing Escape Fraction from Active Galactic Nuclei with Euclid
**PI:** Alexandra Le Reste
**Institution:** University of Minnesota

**Summary:**
A few million years after the Big Bang, the first light sources in the Universe emitted an immense amount of ionizing photons that led to the ionization of almost all gas between galaxies. This event, known as cosmic Reionization, was the last major phase transition in the history of the Universe. While the duration of Reionization is relatively well constrained, the sources responsible for it are still debated, despite the significant resources invested to elucidate this question over the past decades. Two categories of objects are thought to have played a role in the Epoch of Reionization: star-forming galaxies, and accreting super massive black holes, also known as active galactic nuclei (AGNs). Up until recently, star-forming galaxies were the favored candidate, but new observations from the James Webb Space Telescope are revealing unprecedented numbers of super massive black holes, challenging theoretical predictions about the sources of ionizing photons in the Early Universe. Unfortunately, a key quantity is missing to precisely determine the contribution of this primordial black hole population to cosmic Reionization: how many of the ionizing photons produced by these objects manage to escape the surrounding gas to ionize the intergalactic medium. The gas surrounding objects in the early Universe prevents a direct measurement of the escape fraction of AGNs during Reionization: measurements at intermediate redshift are needed to constrain this quantity. Here, we propose to directly measure the escape fraction from AGNs at redshift ~1 in Euclid deep fields by combining all-sky GALEX photometry with Euclid data. This measurement will help refine models for the contribution of accreting black holes to the ionizing photon budget, and will be a decisive step in elucidating the respective contribution of primordial light sources to one of the most researched cosmological periods.

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**24-EGIP24-0035 –** DeepDISC-Euclid: Detection, Instance Segmentation, and Classification for Euclid with Deep Learning
**PI:** Xin Liu
**Institution:** University of Illinois, Urbana Champain

**Summary:**
The Euclid mission, with its unprecedented capabilities for high-resolution wide and deep optical imaging as well as near-infrared imaging and spectroscopy over a third of the sky, presents a unique opportunity to transform our understanding of the dark Universe. A significant challenge in Euclid data analysis is the presence of blended (overlapping) sources, which leads to biased measurements in critical areas such as photometry, photometric redshift estimation, galaxy morphology, and weak gravitational lensing. Addressing this challenge is crucial for ensuring the accuracy of Euclid's scientific outputs.

To address this challenge, we propose the development of DeepDISC-Euclid, an advanced, open-source deep learning framework that efficiently processes Euclid images, accurately identifies blended galaxies, and predicts physical inferences such as photometric redshifts and structural properties with robust uncertainty quantification. This framework will leverage state-of-the-art deep learning techniques, incorporating methods from computer vision that have been highly successful in other domains such as Transformer-based models. A key innovation of DeepDISC-Euclid is its ability to quantify uncertainty in predictions, which is critical for propagating errors into the final cosmological analyses.

The proposed work aims to transform DeepDISC-Euclid from a proof-of-concept into a fully developed, science-ready platform for astronomical object detection, instance segmentation, and classification and physical inferences. This will involve the integration of Detectron2, a next-generation platform for object detection developed for computer vision, into astronomical survey data pipelines. The framework will be trained and validated using a hybrid approach that combines real data with more realistic simulations, leveraging traditional image simulations and advanced deep generative models including diffusion models and Normalizing Flows.

DeepDISC-Euclid is directly aligned with the Euclid mission's goals, addressing the critical need for robust deblending techniques that will enhance the reliability of Euclid's science outputs. Moreover, the framework will be adaptable to other datasets, such as those from the Rubin Observatory, further enhancing its scientific impact. The integration of Euclid and Rubin data will improve the accuracy of photometric redshifts and enable more effective deblending of ground-based images, which Euclid photometric redshift estimation will critically depend on.

The program will deliver a versatile, well-documented software tool, designed for integration into the Euclid NASA Science Center's analysis suite, ensuring broad accessibility and usability within the Euclid research community. The work proposed here is essential for maximizing the scientific return of the Euclid mission, and it aligns with the objectives of the Euclid General Investigator Program, specifically in developing new data analysis techniques and tools that are publicly available.

This project is dedicated to fostering interdisciplinary research and providing early-career training for postdoctoral researchers, graduate students, and undergraduates. The project offers a unique opportunity for participants to contribute meaningfully to cutting-edge research while gaining critical skills in computational astrophysics, data science, and AI-driven research. Early-career researchers will benefit from advanced technical training and leadership development,

positioning them to take on key roles in addressing NASA's strategic objectives. The project is committed to expanding undergraduate research opportunities through structured summer internships focused on AI and data science. These initiatives will provide valuable hands-on experience and equip students with the skills necessary for today's rapidly evolving job market.

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**24-EGIP24-0009 –** Finding and Modeling Strong Gravitational Lenses in Euclid
**PI:** Eugene Magnier
**Institution:** University OF Hawaii

**Summary:**
Strong gravitational lenses are rare chance alignments of massive foreground galaxies with distant background galaxies. They have several exciting and nearly-unique uses in astrophysics studies as both a probe of dark matter and of cosmological parameters. The sensitivity of the lens radius to mass provides a direct measurement of the foreground galaxy masses. The observed distribution of light from the lensed background source galaxies depends on the distribution of mass in the lensing galaxy, allowing us to probe the details of the structure of dark matter in galaxies, including measuring the slope of the mass distribution (a key parameter in understanding the evolution of elliptical galaxies). Additionally, differences in path lengths of the multiple lensed images, coupled with variable or transient signals (e.g. quasars or supernovae), allow us to measure the Hubble expansion parameter (H_0) independently of distance ladder techniques. But to use these exciting tools, it is necessary to find a large, representative, population of strong lenses. In order to effectively use strong lenses to pursue these science goals, lenses identified in imaging surveys require follow-up spectroscopy to determine redshifts, which can then be used to determine high-quality models of the mass distribution of the lens system.

With its excellent spatial resolution and wide area coverage, the Euclid survey provides an an unprecedented opportunity to discover many strong gravitational lenses. Using manual, visual inspection methods, the Euclid Consortium has identified 16 ""sure"" and ""probable"" lenses in ~12,000 galaxies observed in 0.7 square degrees of early release data--a discovery rate of about 1/1000. While the strong lens working group intends to search for lenses in the larger Euclid dataset with their own automated algorithms, and model with their choice of modeling software, we intend to pursue an independent search and characterization effort.

There is a serious need for multiple approaches to this problem. First, even the best lens discovery processes are significantly incomplete; independent searches of the same data sets yield substantially distinct groups of lenses. Second, different teams prioritize different lens systems to target with follow-up spectroscopy. Finally, different teams use different modeling software with different advantages in model convergence, and they make different assumptions about the unconstrained system parameters as part of the model process.

We plan to use our well-tested machine-learning tools to search the Euclid dataset for strong lenses. We will perform follow-up spectroscopy with 8-10m class telescopes, concentrating on the systems with clean single galaxy lenses and single galaxy background sources. We will use public, state-of-the-art modeling software to determine lens mass models for our systems of interest with the goal of measuring the slope of the mass density profile for these systems.

We propose here to use the Euclid early release data and the Q1 data sets to test our search and modeling approaches to be ready to exploit the larger Euclid public data releases in the future. This effort will require re-training our neural network using the Euclid images and simulations guided by those real images. We can use our access to 4m and 8-10m telescopes to obtain follow-up spectroscopy of the best lens systems, given our optimal sample of galaxy-galaxy lenses. We will test the ability of our modeling software to determine lens mass models given both deep ground-based observations, Euclid high-resolution images, and spectroscopic redshifts.

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**24-EGIP24-0034 –** Making a Difference (Image): Transforming Euclid into a Transient Discovery Machine Through Cross-Observatory Synergies
**PI:** Armin Rest
**Institution:** Association of Universities for Research In Astronomy, Inc.


**Summary:**
This proposal seeks to leverage the EWS to unlock rare and powerful high-z transients such as pair-instability and Population III SNe, by creating a cross-telescope transient detection pipeline. We will use the Q1 data release available at the start of this program to develop the software and surrounding infrastructure to detect transients in Euclid data using existing HST/JWST data as templates, as well as in HST/JWST data using Euclid as a template. This will involve techniques that account for differences between the two telescopes' images in terms of their spatial resolution, spatial sampling, depth and wavelength range - a challenging problem, but one that has been addressed for other instruments (e.g., JWST - HST). The discovered transients will be used to train a convolutional neural network (CNN) to identify new transients, and the final pipeline (difference imaging and CNN transient detection) will then be applied to the first EWS data release (DR1) expected in year 2 of the program (still leveraging existing HST/JWST imaging as a template). After DR1, ongoing imaging campaigns with JWST that would otherwise have no reference to search for transients will now be able to use our public pipeline and the Euclid DR1 as a reference, enabling follow-up of interesting transients into the future. In the final year of this program, we will adapt the pipeline to work for Roman - Euclid difference imaging (and vice versa), such that upon the completion of both the EWS and the HLWAS, our pipeline will have enabled a transient search in the full 2,000 square degree of overlap. This is the deepest, widest, repeated near-IR imaging expected for the foreseeable future, but to leverage its potential, we must develop the necessary infrastructure in advance.

Telescopes like JWST and Roman are amazing resources capable of providing a detailed view of rare objects to extraordinary distances, but the enormous area required to detect extremely rare SNe (hundreds or thousands of square degrees) means such observations must be targeted. Euclid, combined with the HLWAS, can provide the detections needed to create a sample of well-observed objects with other resources. Overall this project develops a public tool for cross-telescope difference imaging that can be used for a variety of upcoming NASA telescopes and surveys, and paves the way to unlocking the potential of a massive Roman - Euclid transient survey that is uniquely sensitive to rare high-z SNe.

**24-EGIP24-0010 –** An Investigation of Galaxy Merger Evolution through Morphological Transformations and Star Formation Triggers with Euclid
**PI:** Hayley Roberts
**Institution:** University of Minnesota


**Summary:**
This proposal aims to leverage the depth of Euclid observations and the unique capabilities of the Galaxy Zoo (GZ) team and volunteers to address key questions about galaxy mergers, their substructure, and how they evolve. This includes understanding how mergers trigger star formation, activate active galactic nuclei (AGN), and alter gas within host galaxies. The research plan proposed here is structured into four main science efforts. Project I focuses on identifying and cataloging mergers observed by Euclid. Using results from the main GZ project, we will construct a clean catalog of mergers with additional value-added properties such as mass ratio and merger stage. Project II involves cataloging merger and tidal tail shapes. Volunteers will use Zooniverse's correct-a-machine framework to approve or correct machine-predicted segmentation maps of mergers and tidal tail shapes. Machine-predicted segmentation maps will be produced using Zoobot, and the types of shapes identified will be cataloged and published. Project III investigates the connection between merger morphology and intrinsic host galaxy properties. By leveraging catalogs from Projects I and II, we will compare merger morphology with intrinsic properties such as star formation rates (SFR) and AGN occupation. This will help in understanding the co-evolution of AGN and galaxies, particularly in identifying rare obscured AGN and their feedback to star formation. Project IV focuses on measuring the distribution of gas in mergers using fields with radio survey coverage. By comparing the distribution of visible mass with gas content in galaxy mergers, we aim to understand the impact of mergers on a galaxy's gas content, star formation, and AGN activation. Each of these projects targets different Euclid deep fields, with Projects I and II covering all fields, Project III focusing on Fornax and North fields, and Project IV targeting Fornax and potentially South fields due to radio survey data availability. This comprehensive study will provide significant insights into the dynamics and morphology of galaxy mergers, contributing to our broader understanding of galaxy evolution.

Note: The NOI for this proposal was originally submitted with the title ""Unveiling Galaxy Merger Dynamics and Evolution: Probing Morphological Transformations and Star Formation Triggers with Euclid.""


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**24-EGIP24-0037 –** A comprehensive study of dwarf galaxies in the era of Euclid
**PI:** Aaron Romanowsky
**Institution:** San Jose State University Research Foundation

**Summary:**
Dwarf galaxies are crucial tracers of dark matter and the physics of galaxy formation, while contributing significantly to the assembly of giant galaxies. There are multiple unsolved problems with dwarf galaxies, such as their diversity of sizes, dark matter profiles, and globular cluster systems; their feedback and quenching processes; and their numbers in the field and in denser environments. Even in the nearby Universe, dwarfs are difficult to study observationally owing to their faintness, but the depth and high spatial resolution of Euclid will facilitate their identification and detailed study in large numbers out to redshifts of distances of hundreds of Mpc.

Here we propose to study a sample of thousands of dwarf galaxies and their globular cluster systems in a range of environments, from the field to massive galaxy clusters, using a combination of Euclid imaging along with supplementary imaging and spectroscopy. We will develop and apply photometric methods to estimate distances to the dwarfs, calibrated with spectroscopy. We will also use multiwavelength analysis to estimate the dwarf galaxy sizes, masses, metallicities, star formation histories, internal stellar population gradients, and globular cluster characteristics, while correlating these with morphologies and environments. We will then compare these trends to theoretical models for dwarf galaxy formation. The overall results will provide significant insights to galaxy formation, while the methods will provide readiness to analyze the full Euclid survey in synergy with Rubin, Roman, and DESI.

The project provides key ancillary science results for the Euclid mission, involving the analysis of currently available Euclid data and development of methods for the full survey,  with additional observations and theoretical investigations that support the Euclid data interpretation. The work will contribute significantly to NASA Astrophysics goals in Physics of the Cosmos and Cosmic Origins through the analysis of Euclid data, and through the development of methods that will also be applicable to data from the Roman Space Telescope. Students will be key participants in the project.

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**24-EGIP24-0005 –** Resolving the Local Volume with Euclid

**PI:** Alessandro Savino
**Institution:** University of California, Berkeley

**Summary:**
Euclid has the potential to resolve millions of stars in the Milky Way and in hundreds of galaxies throughout the Local Volume (within approximately 15 Mpc).  However, the default Euclid photometry pipeline is not designed to deal with the crowded fields that are typical of most resolved star studies in the local Universe and it therefore does not allow Euclid to realize its full potential for resolved star studies.  Specialized tools are needed to enable the wealth of resolved star science that Euclid uniquely enables including detecting substructures (e.g., streams, dwarf galaxies) around central galaxies (e.g., M81, M94, M101), the measurement of star formation histories (SFHs), mapping of population gradients, identifying tidal features around Milky Way Globular Clusters, precise distance determinations (e.g., tip of the red giant branch) and the study of luminous red stars in different environments (e.g., asymptotic giant branch stars, core red helium burning stars).

We propose to develop Euclid-specific modules for DOLPHOT, a widely used and publicly available crowded field stellar photometry package. DOLPHOT is the workhorse for resolved star science in the local Universe. It already has modules tailored to HST, JWST, and Roman, which served as the foundation for some of the largest and highest-impact resolved star studies in nearby galaxies (e.g., the Panchromatic Hubble Andromeda Treasury program, measurement of local H0).

We will construct VIS and NISP modules for DOLPHOT (from Q1 datasets) and validate them on Euclid observations of resolved stars (from DR1 datasets). We will make our Euclid modules for DOLPHOT publicly available along with source catalogs of a validator globular cluster field (NGC1851), artificial star tests, and extensive online documentation and tutorials. Our program will provide blueprints for the community to efficiently reduce and analyze Euclid observations of resolved stellar populations.

As part of a targeted science component, we will demonstrate the capabilities of the new DOLPHOT module by analyzing Euclid images of the M81 galaxy group. We will produce and release homogeneous point-spread-function photometry and completeness maps over the full 80 squared-degree extent of the M81 group. We will use these data to: i) measure star formation histories and stellar population gradients over the full stellar halos of M81, M82, and NGC3077; ii) Search and characterize faint satellite galaxies and extended substructures (e.g., streams, tidal dwarfs) in the M81 group.

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**24-EGIP24-0023 –** An Observational Characterization of the Bias and Scatter in Weak Lensing Masses Due to Halo Triaxiality

**PI:** Jack Sayers
**Institution:** California Institute of Technology

**Summary:**
Euclid was conceived to provide transformational constraints on the properties of dark matter and dark energy, and one of its primary tools for this task is a measurement of the halo mass function. Critical to such an analysis is an accurate and unbiased determination of the connection between the survey observables used for halo detection and the underlying halo mass, with Euclid requiring percent-level accuracy in this relation. Gravitational weak lensing (WL) has emerged has the de-facto standard for measuring halo mass, with Euclid likely to provide the best and most complete set of WL measurements over a large fraction of the sky. Almost universally, including for Euclid, the WL mass is obtained by assuming a halo model that is spherical in shape. As a result, the WL mass measurements Euclid obtains will need to be corrected for cluster-to-cluster scatter and on-average bias due to the randomly oriented triaxial shape of the halos in combination with observational projection. To date, all such characterizations of this scatter and bias, including those performed internally by Euclid, have been based on numerically simulated halos. Recently, multi-probe modeling of galaxy clusters has demonstrated the ability to measure the axial ratios and orientation of the dark matter halo, thus allowing for direct observational constraints of the scatter

and bias between spherical WL masses and the underlying triaxial mass. Essential to this multi-probe modeling are deep observations of the cluster gas in both X-rays and the Sunyaev-Zel'dovich effect, with the CHEX-MATE sample providing uniform coverage in these observables for a sample of 118 objects . From the CHEX-MATE sample, we propose to determine both spherical and triaxial halo masses from wide-field ground-based WL data to obtain the first-ever observational determination of the scatter and bias due to triaxiality and orientation. We will measure the WL bias to percent-level precision, a critical benchmark for assessing the mass calibration of the Euclid survey.