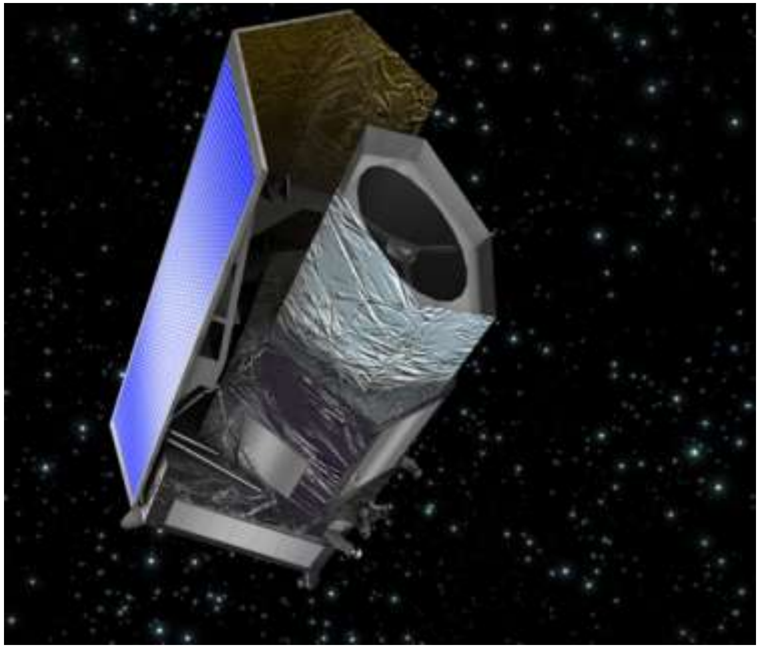
Astrophysics
Division

Euclid



05 November 2013

Jason Rhodes (NASA JPL)
Paul Hertz (NASA HQ)

Top-level Science Objectives for Euclid

1. ***Dark Energy Properties***. Measure the Dark Energy equation of state parameters, w_p and w_a. When combined with additional probes and results from *Planck*, the constraints on w_p and w_a improve to 0.7% and 3.5% precision, respectively. *The combined figure-of-merit represents more than a 300-fold improvement on our best current constraints.*

2. ***Beyond Einstein's Gravity***. Distinguish General Relativity from modified-gravity theories by measuring the galaxy clustering growth factor exponent, γ, with a precision of 2%.

3. ***The nature of dark matter***. Test the Cold Dark Matter paradigm for structure formation, and measure the sum of the neutrino masses to a precision better than 0.02 eV when combined with results from the *Planck* mission.

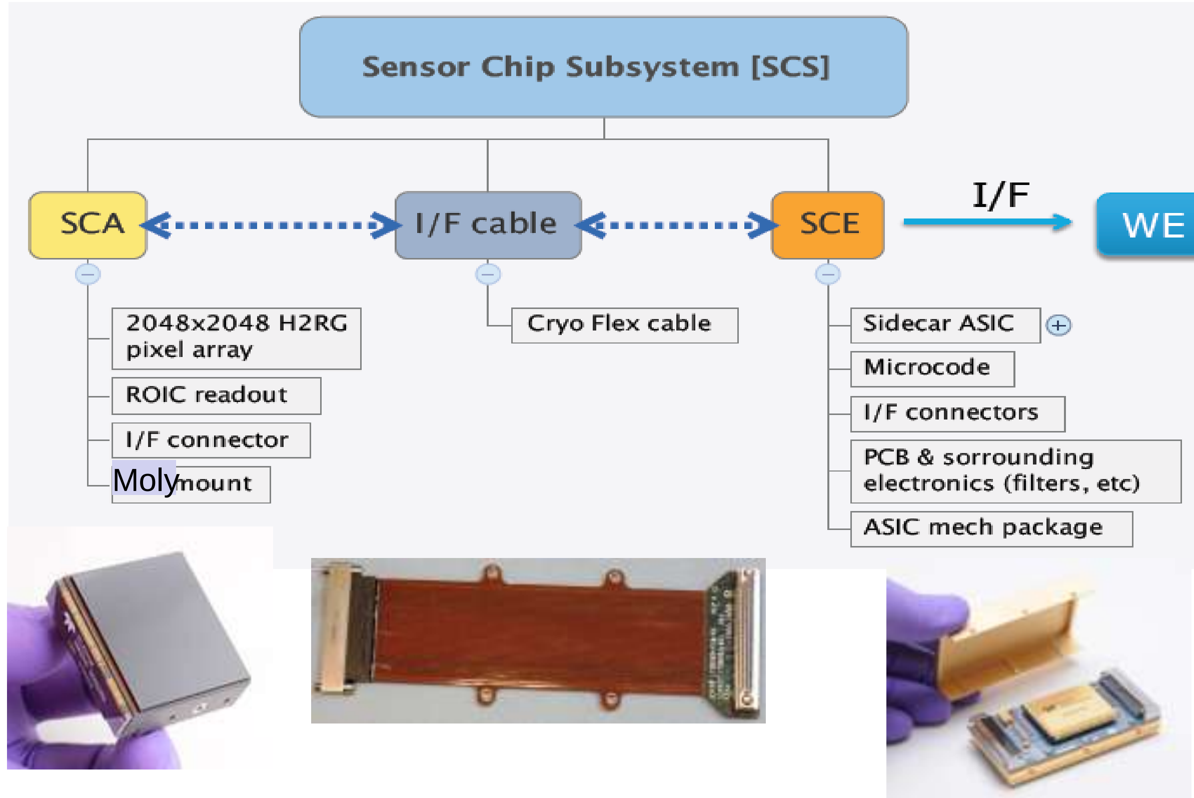
4. ***The seeds of cosmic structure***. Improve by a factor of 20 the determination of the initial condition parameters compared to *Planck* alone. These parameters include the index of primordial power spectrum fluctuations, n, the power spectrum amplitude, σ_8, and the non-gaussianity parameter, f_{NL}.

NASA Hardware Participation: IR detectors (1)

NASA will deliver to ESA:

- 16 flight "triplets"
- 4 flight spares

Triplets will be integrated into the NISP instrument, provided by the Euclid Consortium



Triplet = detector (SCA) + cryogenic cable + cold readout electronics (SCE)

- SCAs: 2.3 um cutoff 2k x 2k HgCdTe detectors. Euclid custom Molybdenum mount.
- Low thermal conductance cryo cable. Copper traces, constantan ground plane.
- SCEs: Cold readout electronics based on SIDECAR ASIC. Includes firmware and mechanical packaging.

NASA Hardware Participation: IR detectors (2)

NASA role is not just a pass though for focal plane component contracts.

- Characterization of the near-IR triplets is key: it is both **necessary** to support science observations, and provides **value-added synergies**
  - US participation in *ESA Euclid Calibration Working Group* provides strong coordination with NASA testing activities.
  - US participation in *ESA-EC-NASA NIR Detector Working Group* improves coordination with EC characterization activities.
  - NASA system engineering capabilities enhance NISP's near-IR sensor chip systems by:
    - Detailed work on reliability (e.g., detector construction and processes).
    - Design and modeled performance of cryo-cables.
    - Electrical and data interface designs based on extensive heritage
- NASA Centers offer these key, unique characterization capabilities
  - GSFC Detector Characterization Lab
    - Extensive performance characterization at both component and integrated triplet level for all flight parts and spares.
  - JPL/Caltech Projector Lab
    - Specific, additional characterization on select aspects (i.e., intrapixel response).

Current US Science Participation in Euclid

- Jason Rhodes - member of Euclid Consortium Board, ESA Euclid Science Team
- Michael Seiffert (JPL) - Project Scientist and full member in Euclid Consortium

US science teams:

- "Precision Studies of Galaxy Growth and Cosmology Enabled Through a Physical Model for Nebular Emission", PI Chary (Caltech), 3 new EC members
  - Studies the effect of dust and glowing gas on galaxy spectra, to obtain better distance (redshift) estimates from the measured colors.
- "Looking at Infrared Background Radiation Anisotropies with Euclid", PI Kashlinsky (at GSFC), 7 new EC members
  - Studies unresolved infrared background light from the earliest galaxies, to infer the pace of early star formation.
- "Constraining Dark Energy and Gravity with Euclid", PI Rhodes (JPL), 29 new EC members + 14 pre-existing EC members
  - Measures dark energy and how mass is distributed on the largest cosmic scales, through weak lensing (distortions of galaxy shape), baryon acoustic oscillations (galaxy clustering), and supernova explosions; studies how galaxies form by observing the most youthful (high-redshift) objects
- US Members now well integrated into consortium & leading key work packages.

Study for NASA Euclid Science Center

IPAC is leading a *study* for a NASA Euclid Science Center (NESC), with goals to:

- Support selected teams and archival research community
- Optimize exploitation of IR detectors
- Establish US "Science Data Center" – access to information, data, reduction software for US teams and US science community

Preliminary IPAC Report details potential scope, if budget allows:

- US community support.
- Archive and support of NIR detector characterization data
- NIR instrument pipeline contributions: algorithms and software for basic reduction, photometric quality, spectral extraction and cleaning.
- Participation in Mission Verification
- Contribution to survey planning tools, serve as interface to ESA Science Operations Center
- Participation in Level 1 data quality assessment

NASA's decision will be made in context of FY2015 President's Budget Request

NESC tasks as preparation for WFIRST

Substantial synergy in tasks identified for the NESC with WFIRST-AFTA needs:

- Highly accurate relative photometry is needed for photometric redshifts:
  - Bad pixel identification: detector latency (image persistence) requires tracking the observation history of each pixel. Allowing for a decay time after observing a bright star may not be sufficient: the noise model for an affected pixel may require an additional component.
  - Dark subtraction: a key element for relative photometry, leverages US expertise in NIR detectors. At high precision levels, the distinction between dark current and other effects becomes blurry, and a more sophisticated noise model may be required.
- Absolute photometry / flux calibration:
  - Flux calibration is a critical part of setting exposure times and deciding dither strategy, and will be used for photo-zs for Euclid and WFIRST.
- Euclid and WFIRST both require 2D slitless grism spectral decontamination
  - Key requirement for Galaxy Clustering measurements. Successfully employed on HST – but Euclid and WFIRST will be treading new ground in the extremely wide sky area and the required freedom from systematic error in redshift precision.
- Euclid and WFIRST will use the same detector family (HXRG).

NASA Investment in Euclid

Lifecycle costs for the hardware contribution and the US Euclid Science team were confirmed at KDP-C on13 September 2013, at $101.4M

Hardware Activities*	$45.4M
Science Team	$50.0M
Study for NASA Euclid Science Center	$1.0M
HQ-held reserves (UFE)	$5.0M

* Hardware activities include
  - Estimated $15M-$20M hardware contract to Teledyne
  - NASA project management, including project-held reserves
  - Detector characterization at JPL and at GSFC

The potential budget for a NASA Euclid Science Center is ~$45M. A NASA Euclid Science Center funded at this level would bring the lifecycle cost to $146.4M.

Euclid survey data will become public, with releases starting 1-2 years after the survey begins. NASA will compete GO funding for US investigators, either through a dedicated Euclid GO program or through ADAP – this is TBD.

NASA's plan for participation in Euclid

NRC Report "Assessment of a Plan for U.S. Participation in Euclid" (Feb 2012)

"NASA should make a hardware contribution of approximately $20 million (FY12 dollars) to the Euclid mission to enable U.S. participation."

- The Teledyne hardware contract is estimated at roughly $15M-$20M (RY dollars).

"In exchange for this small, but crucial contribution, NASA should secure through negotiation with the European Space Agency both a U.S. position on the Euclid Science Team with full data access and the inclusion of a team of U.S. scientists in the Euclid Consortium that would be selected by a peer-reviewed process with full data access as well as authorship rights consistent with Euclid policies still to be formulated."

- Jason Rhodes is a member of the ESA Euclid Science Team; 40 scientists selected by NASA peer review were added to the Euclid Consortium with full data and authorship rights.

"NASA should seek independent community review of any financial commitment for hardware expenditures beyond $30 million for Euclid."

- NASA plans hardware expenses of $45.4M; this has not changed since NASA presented the project to the CAA in March 2013.
- This presentation lays out NASA's plans for participation in Euclid, their total cost, and the anticipated science return, for discussion with the CAA of the value of a potential NASA Euclid Science Center.

Summary

Why is NASA not acting as a pass-through for an IR detector contract, as envisaged when the NRC assessed the plan in 2011-2012?

- Such a minimal contribution was not acceptable to ESA

Robust science participation in Euclid helps prepare for WFIRST-AFTA:

- Science objectives are complementary; overlap in techniques and methods
- Evidenced by Euclid scientists who are members of WFIRST-AFTA SDT: David Spergel, Jason Rhodes, Daniel Stern, Yannick Mellier, Saul Perlmutter, Chris Hirata, Yun Wang

NRC Report "Assessment of a Plan for U.S. Participation in Euclid" (Feb 2012):

"This investment should be made in the context of a strong U.S. commitment to move forward with the full implementation of WFIRST in order to fully realize the decadal science priorities of the NWNH report."

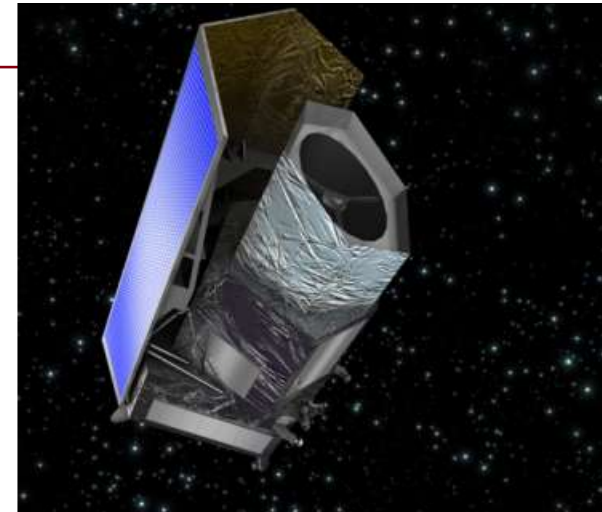
- NASA is maturing technology and conducting concept studies for different WFIRST architectures including WFIRST-AFTA
- NASA is making the investments required to be prepared to start WFIRST-AFTA as soon as funding is available, once JWST is completing development, and potentially as early as FY 2017

Backups

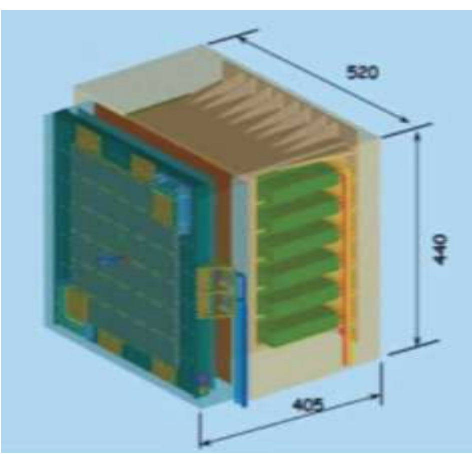
Euclid Mission Overview

Salient Features

- Category 3, Risk Class B
- ESA Cosmic Vision 2015-2025 Mission, M-Class
- Optical and NIR Observatory with 1.2-m Telescope
- U.S. Providing Characterized NIR Detectors
- U.S. Science Investigators selected by NASA
- Launch Date: mid-2020, 6 year nominal mission
- Data public after proprietary period in sequenced data releases



Two instruments: a visible imager (VIS) and a NIR imager-spectrometer (NISP)



VIS Focal Plane

36 4k x 4k CCDs
Cooled to 150 K
0.55 – 0.9 um

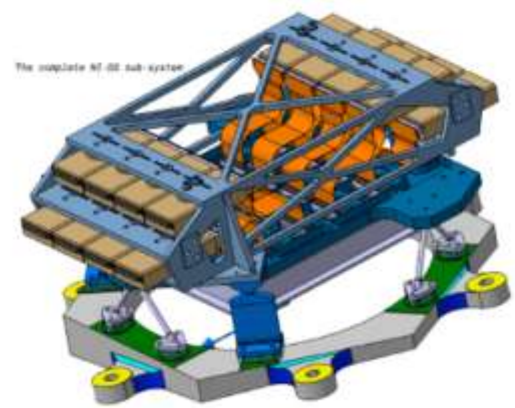


Figure 2 Conceptual view of NI-DS.

NISP Focal Plane

16 2kx2k HgCdTe
100 - 150 K
0.92 – 2.02 um

Euclid Surveys

- Euclid science objectives translate into two primary Euclid surveys for which it is optimized:
  - Weak Lensing survey
  - Galaxy Clustering survey (Baryon Acoustic Oscillations / Redshift Space Distortions)
- Additional science is derived from the combination of the surveys with each other and with other data sets and from their legacy value.
- 15,000 square degree survey, with near-IR imaging and spectroscopy
  - The Euclid NISP instrument uses 3 band photometry supplemented with ground-based multi-band measurements to estimate the photometric redshifts of ~2 billion weak lensing galaxies. 24 mag, 5 sigma point source
  - The Euclid NISP instrument uses slitless spectroscopy to measure the redshifts of ~50 million galaxies. Redshift is determined from the Halpha line. 3.5 sigma line flux limit of 3×10^{-16} ergs/cm^2/sec
- Additional > 40 square degree deep survey, 2 mag deeper than wide survey

Current US Membership in Euclid Consortium

New Members

Richard Arendt, NASA Goddard Space Flight Center
Matthew Ashby, Smithsonian Astrophysical Observatory
Rachel Bean, Cornell University
Charles Bennett, Johns Hopkins University
Gary Bernstein, University of Pennsylvania
Mark Brodwin, University of Missouri at Kansas City
Volker Bromm, University of Texas
Daniela Calzetti, University Of Massachusetts, Amherst
Ranga Ram Chary, California Institute of Technology
Asantha Cooray, U California at Irvine
Peter Eisenhardt, Jet Propulsion Laboratory
Daniel Eisenstein, Harvard University
Richard Ellis, California Institute of Technology
Jonathan Gardner, NASA Goddard Space Flight Center
Anthony Gonzalez, University of Florida
Guenther Hasinger, University of Hawaii
Christopher Hirata, California Institute of Technology
Shirley Ho, Carnegie Mellon University
Bhuvnesh Jain, University of Pennsylvania
Steven Kahn, Stanford University
Alexander Kashlinsky, NASA Goddard Space Flight Center
Alina Kiessling, Jet Propulsion Laboratory
Eric Linder, Lawrence Berkeley National Laboratory
Robert Lupton, Princeton University
Rachel Mandelbaum, Carnegie Mellon University
Marisa March, University of Pennsylvania
Dan Masters, California Institute of Technology IPAC
Harvey Moseley, NASA Goddard Space Flight Center
Leonidas Moustakas, Jet Propulsion Laboratory
Nikhil Padmanabhan, Yale University
Michael Seiffert, Jet Propulsion Laboratory
David Spergel, Princeton University
S. Adam Stanford, University of California, Davis
Daniel Stern, Jet Propulsion Laboratory
Michael Strauss, Princeton University
Harry Teplitz, California Institute of Technology
Risa Wechsler, Stanford University

Additional Members who were already part of the EC

Steven Allen, Stanford University
Chris Bebek, Lawrence Berkeley National Laboratory
Peter Capak, California Institute of Technology
Olivier Dore, Jet Propulsion Laboratory
Alex Kim, Lawrence Berkeley National Laboratory
Michael Lampton, Lawrence Berkeley National Laboratory
Michael Levi, Lawrence Berkeley National Laboratory
Brice Menard, Johns Hopkins University
Peter Nugent, Lawrence Berkeley National Laboratory
Saul Perlmutter, Lawrence Berkeley National Laboratory
Jason Rhodes, Jet Propulsion Laboratory
Claudia Scarlata, University of Minnesota
David Schlegel, Lawrence Berkeley National Laboratory
Yun Wang, University of Oklahoma

Euclid Data Release

- Q2 2020 Launch

- "Quick release" data releases at 14, 38, 62, 74 months
    - Not suitable for cosmology (small area)

- Full releases at:
    - 26 months (2500 sq deg)
    - 50 months (7500 sq deg, cumulative)
    - 74 months (15000 square degrees cumulative)

EC Publication Policy

- Three types of publications handled by different internal Euclid Consortium Publication Groups (ECPG)
  1. Science
  2. Technical
  3. Data release
- ECPG is first step in initiating any Euclid-relevant paper, even if it does not contain proprietary information
- Euclid Consortium Editorial Board handled internal review and refereeing, authorship
  - Composed of ECL, ECPG chairs, SWG coordinators, EST, SGS scientist, ESA project Scientist, VIS and NISP instrument leads
- Tiered membership in Consortium determines authorship rights by integrated work years
  1. Founder; all papers
  2. Long Term contributor; >4 WY; all primary program papers and all papers in their science/technical area
  3. Member; > 2 WY Primary papers and some papers in their science/technical area
  4. Associate; <2WY papers they contribute to
- Task force has been set up to evaluate contributions to determine membership level
  - Rhodes is on task force, first meeting will be July 2013
- Publication policy is under ECB control
- EC members must accept publication policy or forfeit membership

NASA Euclid Participation: Additional Benefits

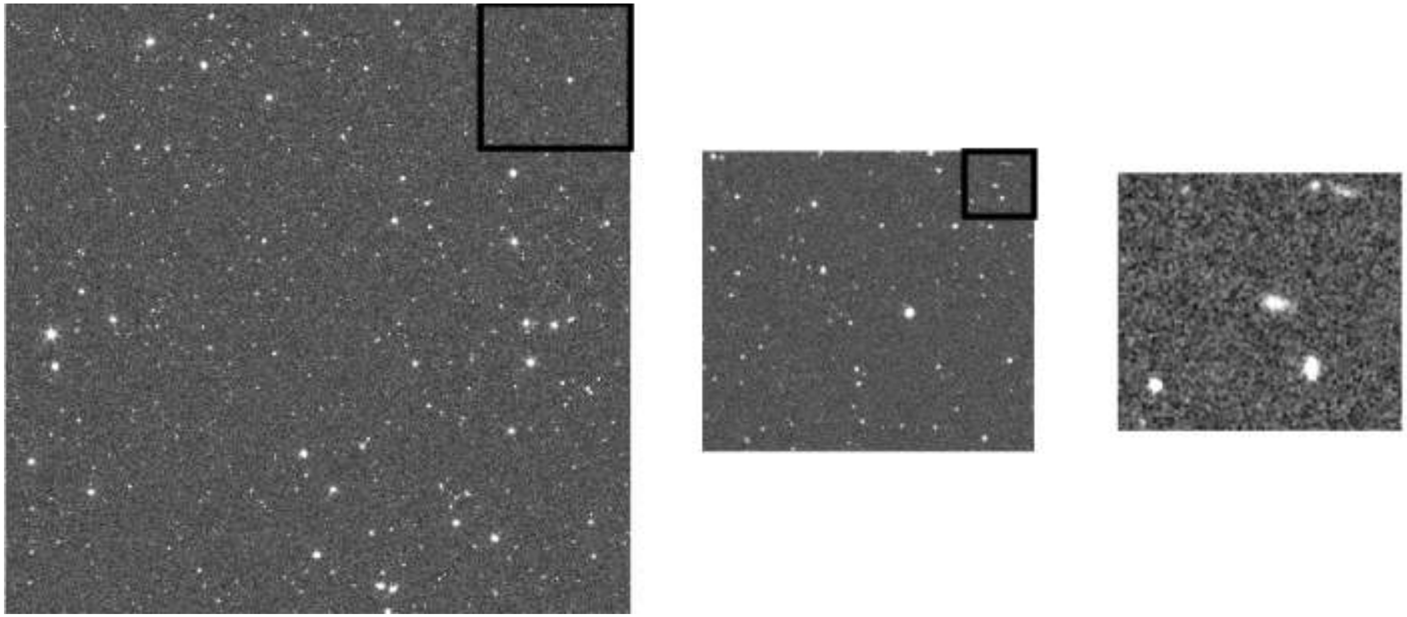
Robust Euclid science participation helps prepare for WFIRST-AFTA:

- Complementary science objectives, but with overlap in techniques and methods
- Evidenced by Euclid scientists who are members of WFIRST-AFTA SDT: David Spergel, Jason Rhodes, Daniel Stern, Yannick Mellier, Saul Perlmutter, Chris Hirata, Yun Wang.

Potential for data processing and reduction participation (NESC) has strong synergy with WFIRST-AFTA (previous slide).

Support for the US Euclid teams and Archival Research community, through deep knowledge of Euclid data gained by participation in the Science Ground Segment and Science Operations, leads to enhanced science return.

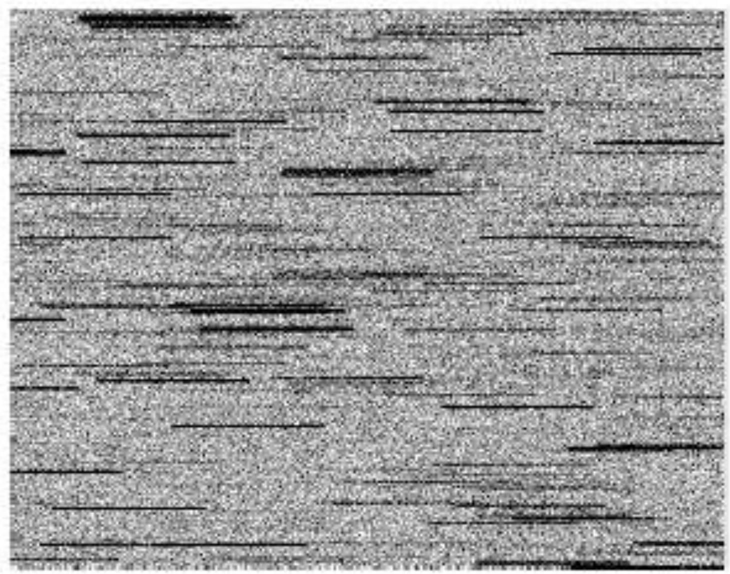
Euclid NISP Photometry

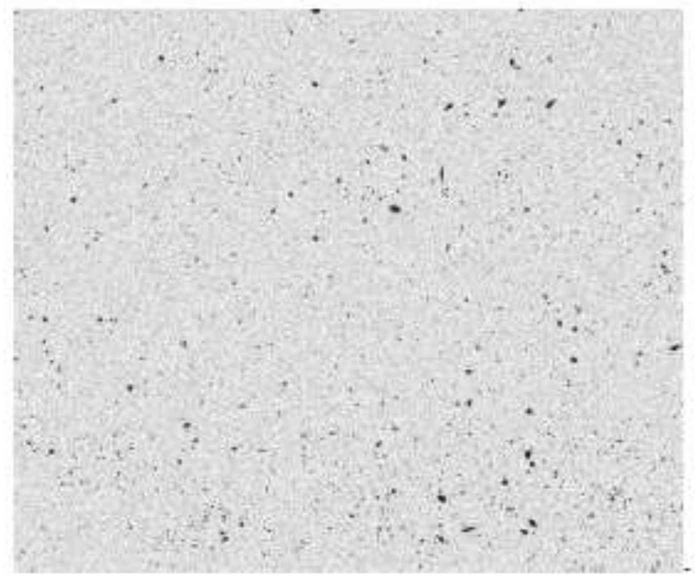


The Euclid NISP instrument uses 3 band photometry (one band simulated here) supplemented with ground-based multi-band measurements to estimate the photometric redshifts of the weak lensing galaxies.

The wide-field deep photometry need is best accomplished from space, hence the need for the IR focal plane.

Euclid NISP spectroscopy





The Euclid NISP instrument uses slitless spectroscopy (simulated here) to measure the redshifts of ~ 50 million galaxies

Redshift is determined from the Halpha line, which falls in the near-IR for interesting redshifts, hence the need for the IR focal plane.