Euclid Spectroscopic Image Simulations and Reconstruction

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Neutrino Telescopes 2023

The Euclid Mission

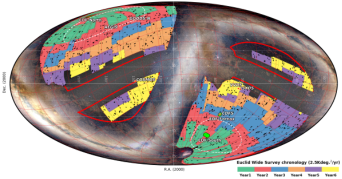
Euclid is a space mission of ESA, launched on the 1^{st} July 2023.

- Science objectives:
  - Test General Relativity
  - nature of dark energy
  - initial conditions
  - absolute neutrino mass

Credits: ESA

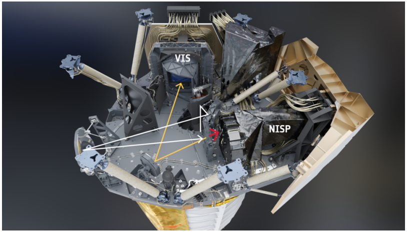
- It will observe the sky from the L2 lagrangian point for 6 years

- Largest redshift survey:
  - **15000 deg^2**
  - redshift $\mathbf{0.9 < z < 1.8}$



Euclid Collaboration: Scaramella et al. 2022.

The Spacecraft



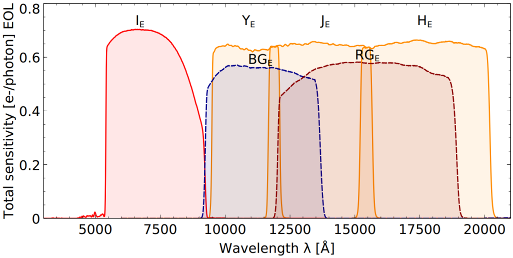
Credits: ESA

VIS (Visible)

- Photometry: I_E

NISP (Near-Infrared)

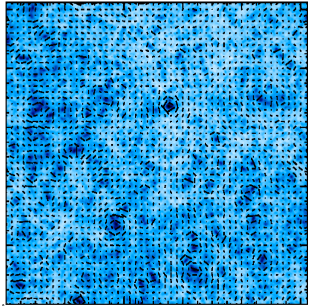
- Photometry: Y_E, J_E, H_E
- Spectroscopy: BG_E, RG_E



Euclid Collaboration: Scaramella et al. 2022.

Cosmological probes

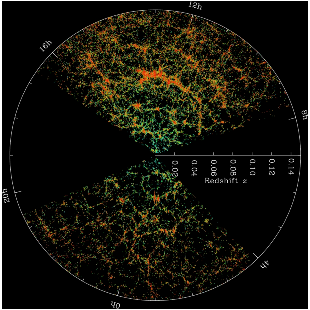
Weak Lensing $\sim$ 1.5 G galaxies



arXiv:0908.4157

- 2D-Position (RA, DEC)
- Shapes
- Photometric redshift

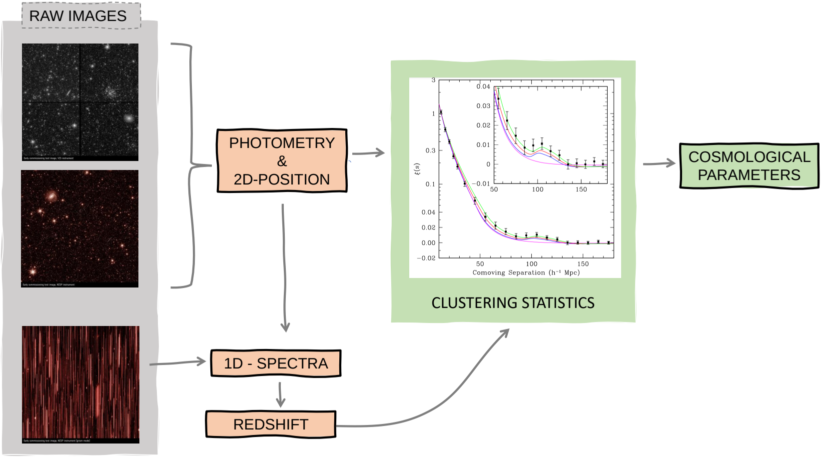
Galaxy Clustering $\sim$ 30 M galaxies



SDSS-III

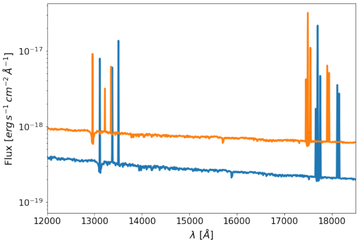
- 2D-Position (RA, DEC)
- Spectroscopic redshift

Data Processing in Galaxy Clustering



→ Talks by Laureijs and De Caro

Measurement of the Redshift



Redshift determination:

1. Aquisition of the Dispersed Image
2. Extraction of the 1D spectra
3. Line identifications

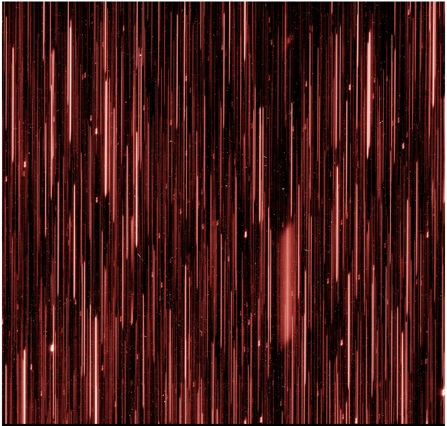
Requirement

$$\sigma(z) = 0.001(1+z)$$

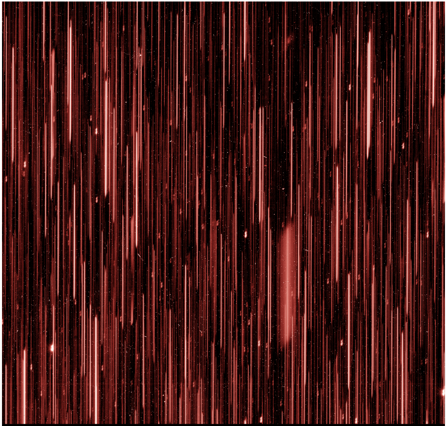
for a source of 0.5" in diameter $\rightarrow$ minimum resolving power of $\mathcal{R} = \lambda/\Delta\lambda = 300$.

We have developed a runner (`SPRING`) to performe customized simulations and process of data with Euclid official codes to study the performance and the systematics.

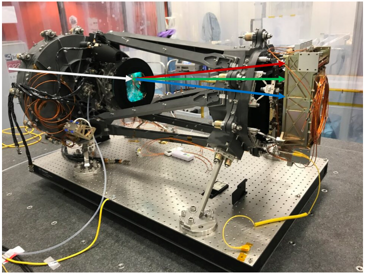
Dispersed Image


Early commissioning test image, NISP instrument (grism mode)

Dispersed Image



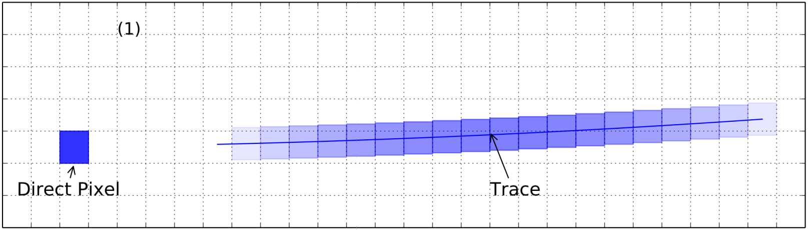
Early commissioning test image, NISP instrument (grism mode)



Credits: ESA

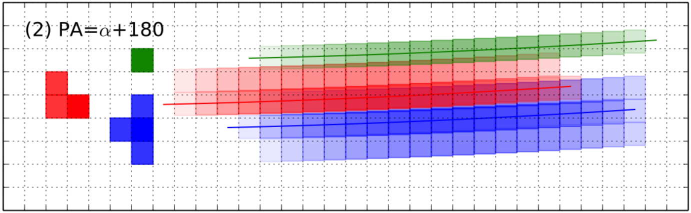
Slitless Spectroscopy
=
All the incoming light is dispersed

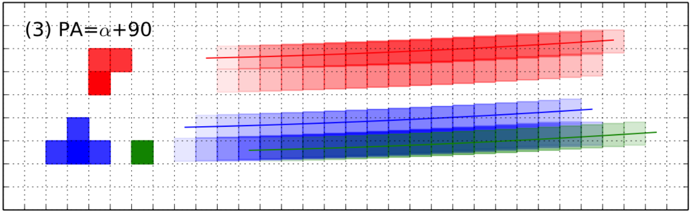
Dispersed Image - Point Like Source



jwst-docs.stsci.edu

Dispersed Image - Cross Contamination





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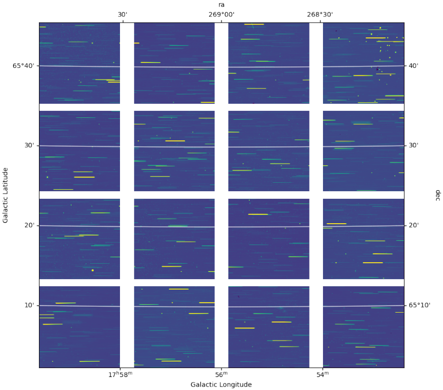
→ Observation with 4 different dispersion direction

Spectroscopic Simulator

Pixel Simulation

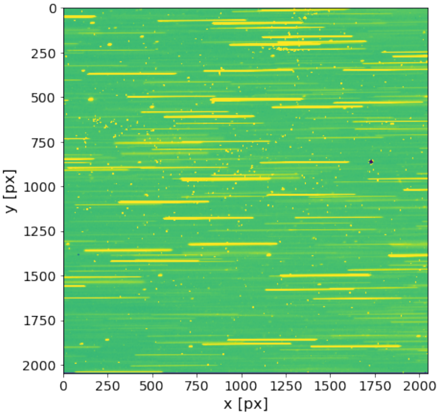
4x4 detectors with 2048x2048 pixel each

- Optical Model
- Detector effects: non-linearities, bad pixels
- Cosmic Rays, zodiacal light
- Readout mode



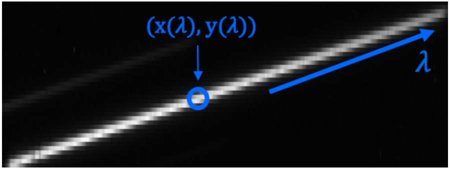
Spectra Extraction

1. Pre-Processing: correction of detector non-idealities



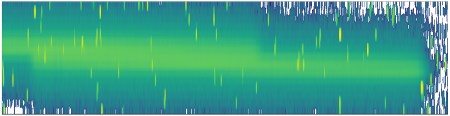
Spectra Extraction

1. Pre-Processing: correction of detector non-idealities
2. Location of the sources from the photometry



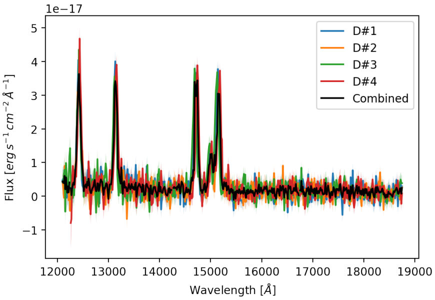
Spectra Extraction

1. Pre-Processing: correction of detector non-idealities
2. Location of the sources from the photometry
3. Decontamination of overlapping spectra



Spectra Extraction

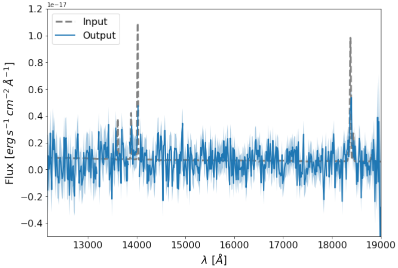
1. Pre-Processing: correction of detector non-idealities
2. Location of the sources from the photometry
3. Decontamination of overlapping spectra
4. Combination of different observations



Accuracy of the Redshift

Euclid Target Galaxies

$$(0.9 < z < 1.8) \text{ and } > f_{H\alpha} = 2 \cdot 10^{-16} erg\, s^{-1}\, cm^{-2}$$



Failure of the measurement:

- Misidentification of the Hα
- Peak noise as $H\alpha$

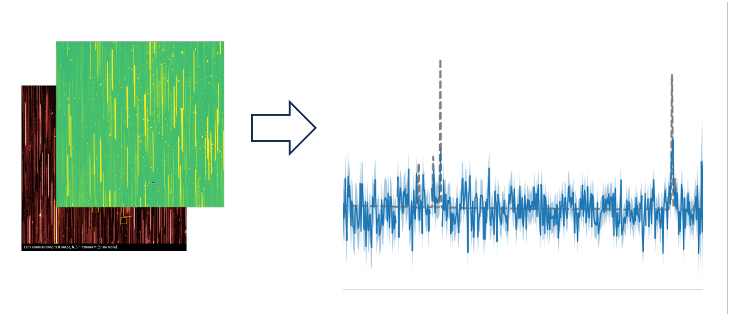
We will use pixel simulations to evaluate the systematics by measuring:

- Purity $P = \frac{\# z_{\text{correct}}}{\# z_{\text{measured}}}$
- Completeness $C = \frac{\# z_{\text{measured}}}{\# z_{\text{total}}}$

Evaluation of Unknown Systematics

Injection of Fake Sources

Adding simulated spectra into real data and re-processing them with the offical pipeline allow us to inherit properties of the image that are otherwise difficult to model



Outlook

- July 2023: launch of the satellite
- Now: PV-Phase for calibrations and characterization
- **February 2024: start of the Euclid sky survey**
- February 2025: First ”Quick” release
- February 2026: First Data release

Abstract

Euclid is a European Space Agency (ESA) mission, designed to investigate the nature of Dark Energy and Dark Matter. It will measure the positions, shapes, and colors for billions of galaxies, and also redshift for a subset of tens of millions of those galaxies to map the matter distribution with unprecedented accuracy. The satellite launch took place in July 2023, and the data taking will last for six years covering one-third of the entire sky.

To attain the desired level of precision in parameter estimation, meticulous management of systematic effects is required. These effects have both hardware and astrophysical origins: the former includes detector non-idealities and telescope response; the latter includes cosmic rays, background light, and signal contamination from different sources.

In order to quantify the efficiency in the redshift reconstruction, we have developed the Spectroscopic Pipeline Runner and INput Generator (SPRING) which runs pixel-level simulations and performs the data processing through Euclid spectroscopic pipeline. SPRING is a runner of Euclid official codes suitable for quantifying systematics. It allows us to simulate both realistic images of the sky and non-astrophysical sources to properly evaluate instrumental effects.

Authors

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Key-words: *cosmology*, *systematics*, *slitless spectroscopy*

References

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- Euclid Collaboration: Gabarra et al., (2023) A&A, 676, A34, DOI: 10.1051/0004-6361/202346177

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