Deblending and Photometry of Faint Sources using VAEs and Multi-Wavelength Data

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ML4ASTRO2
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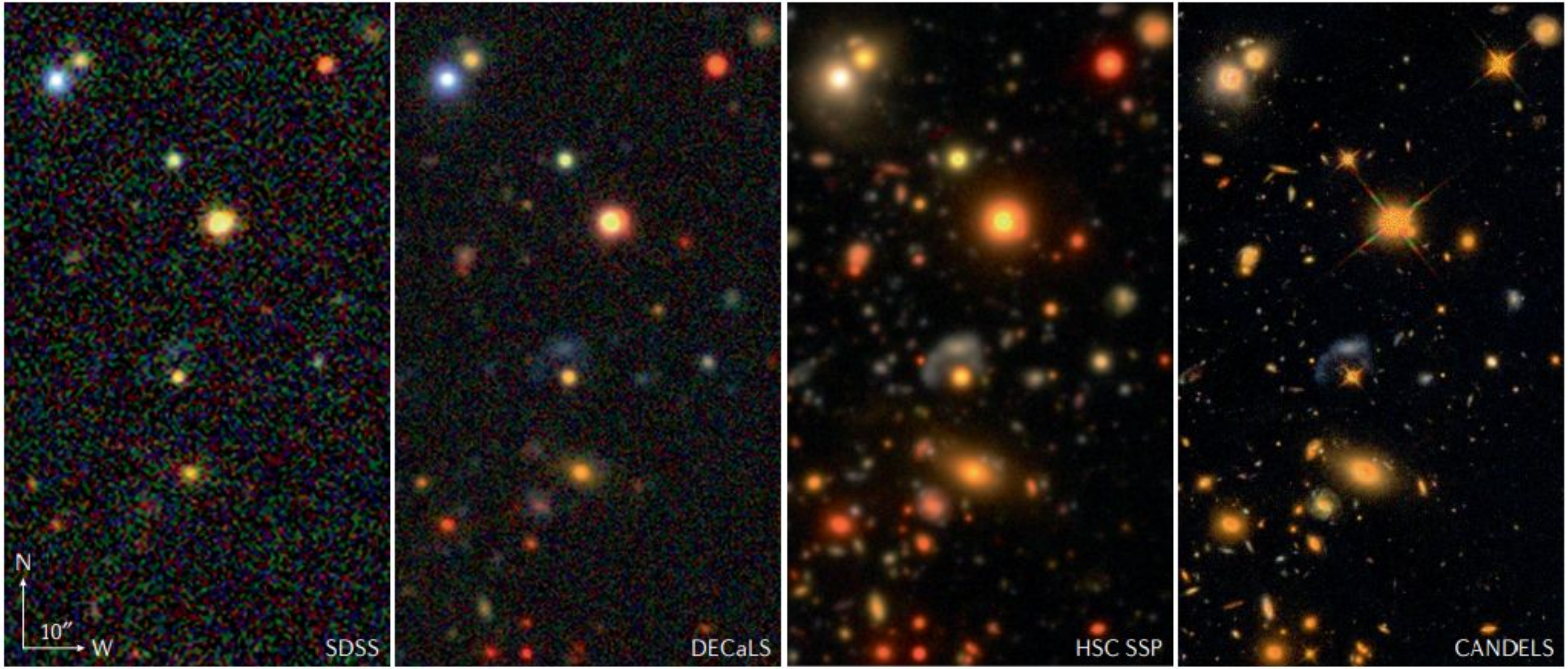
The Source (De)Blending Problem

what's source deblending?

Source deblending is a process in astrophysics and astronomy used to separate the light or emission from multiple overlapping astronomical sources or objects that are close to each other in the sky. When observing distant celestial objects, such as galaxies, stars, or quasars, they often appear close together in the field of view of telescopes. This can make it difficult to study and analyze each source individually, especially when their emissions overlap.

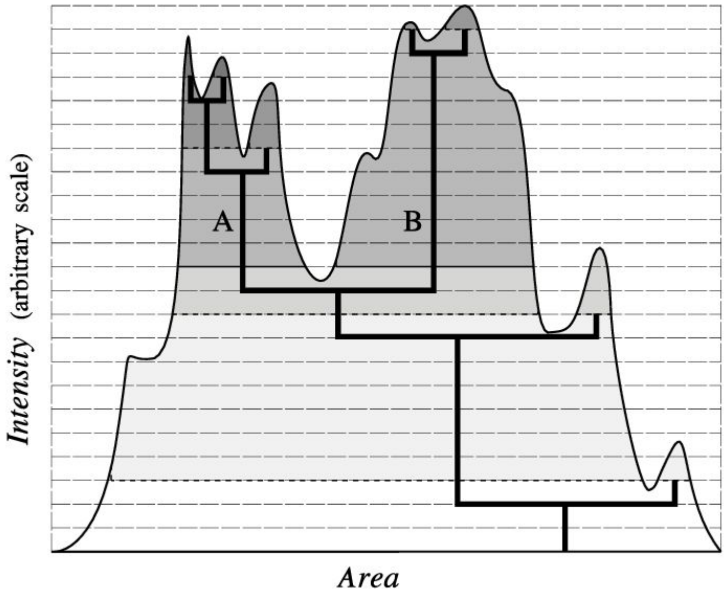
Source deblending involves computational techniques and algorithms to separate the contributions of each source from the combined signal received by the telescope. The goal is to obtain accurate measurements and characteristics for each individual source within a crowded or blended region.

The Same Sky Patch: 1.5 x 0.75 arcmin²



ps = 0.396’’ | ps = 0.262’’ | ps = 0.168’’ | ps = 0.06’’

Classic Solution: SExtractor Deblender



Parameter	Setting	Comment
DETECT_MINAREA	5	Minimum number of pixels above threshold
DETECT_THRESH	2	Detection Threshold in σ
ANALYSIS_THRESH	2	Limit for isophotal analysis σ
FILTER	Y	Use filtering
DEBLEND_NTHRESH	64	Number of deblending sub-thresholds
DEBLEND_MINCONT	0.0	Minimum contrast parameter for deblending
CLEAN	Y	Clean spurious detections
CLEAN_PARAM	1	Cleaning efficiency
MASK_TYPE	CORRECT	Correct flux for blended objects

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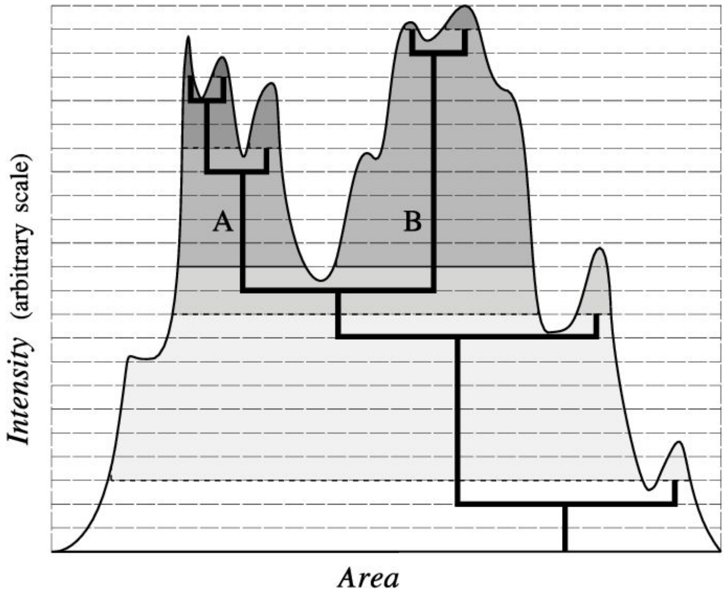

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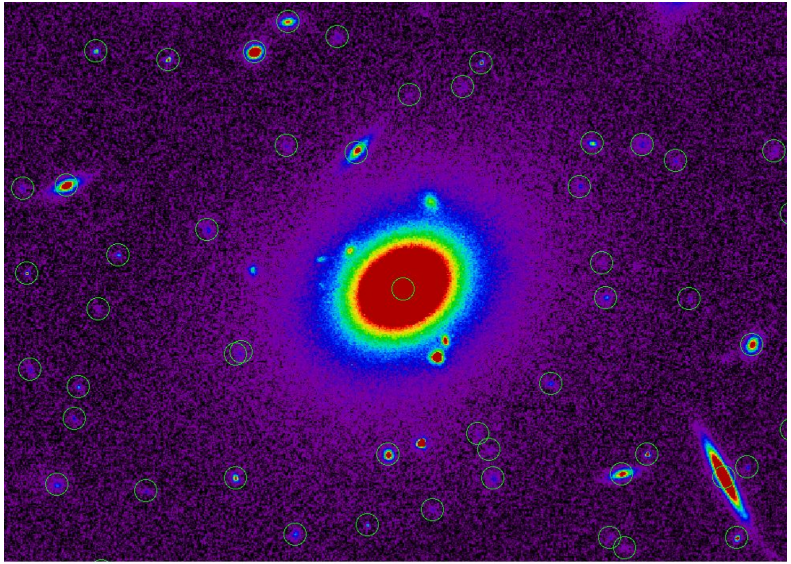
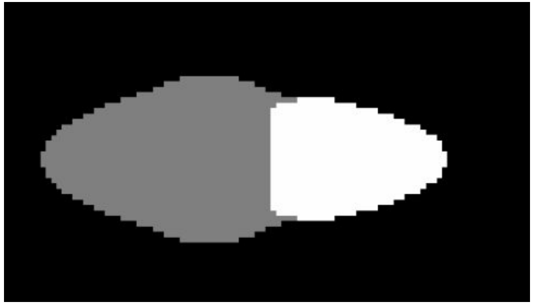
Deblending in Practice #1: Problem's Subjectivity

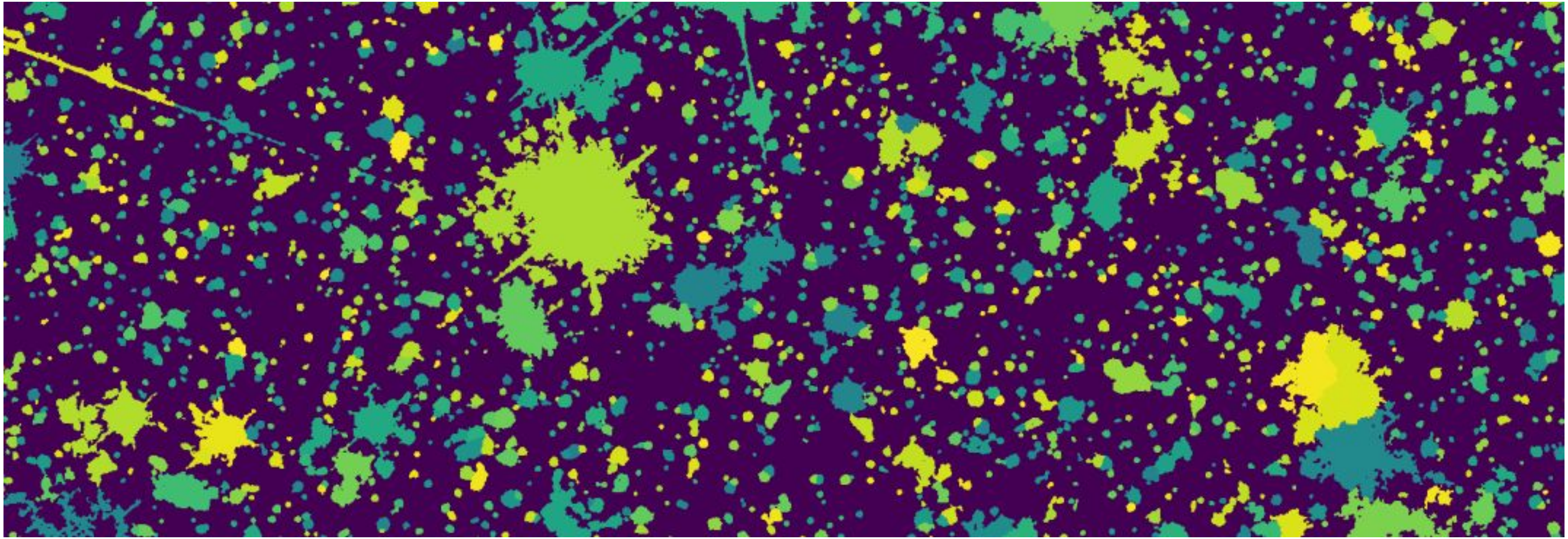




Subjectivity of what is supposed to be a good deblending
Opposite ideas according to the specific science case

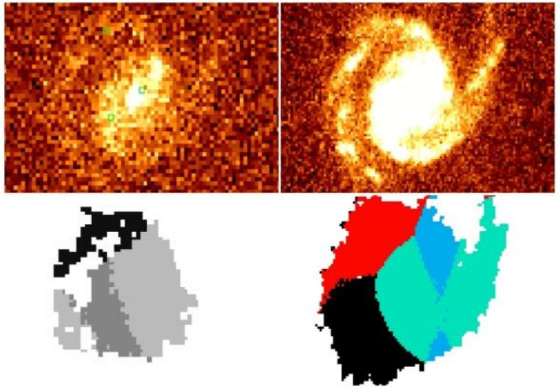
Typical limitations of traditional methods

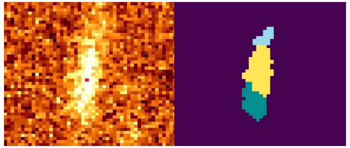
Deblending in Practice #2: Crowded Fields/Dense Environments



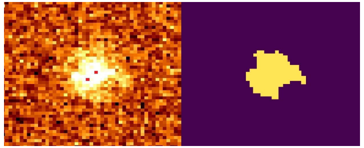
Deblending in a dense region with many bright stars
Spikes from saturated stars make things even more complex

Deblending in Practice #3: Realistic Morphologies

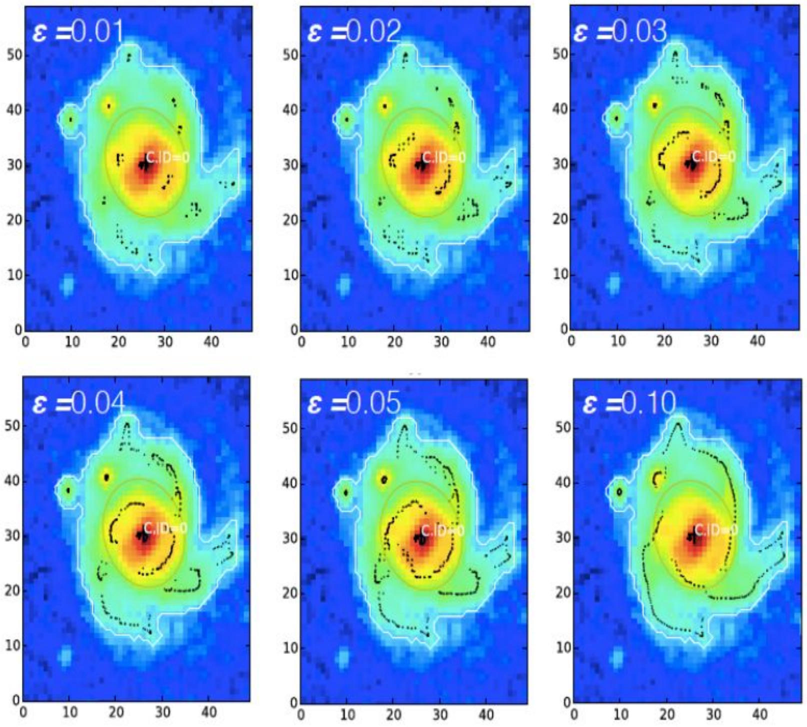




Over-Deblended

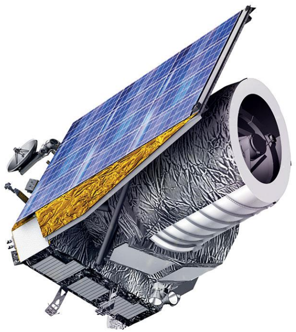


Under-Deblended



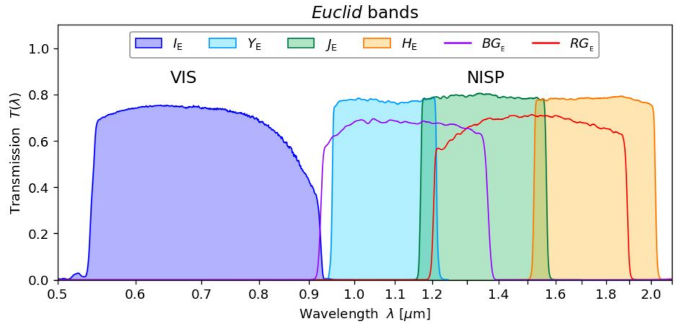
Different hyper-parameter configurations lead to extremely different results
Depth, evidently, plays a major role concerning deblending results

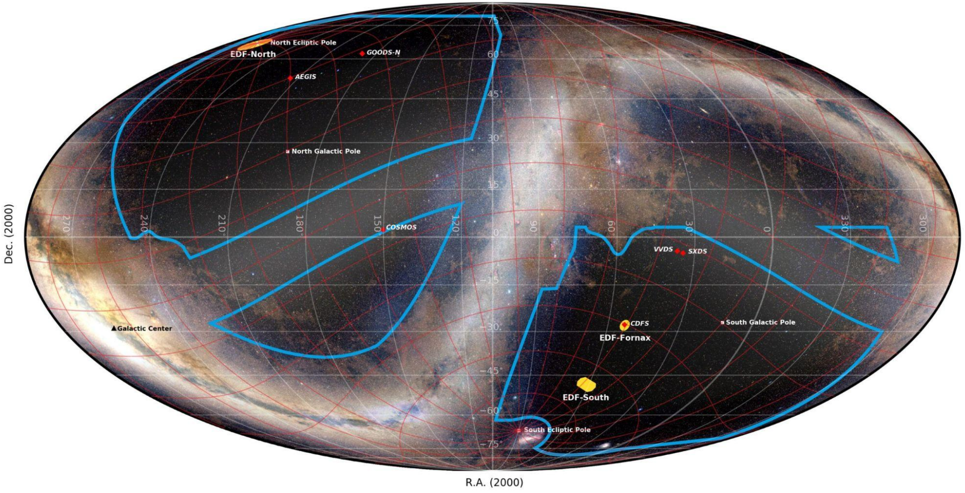
Euclid: Exploring the Dark Universe



Euclid is a cosmology survey mission optimized to determine the properties of dark energy and dark matter

- ★ Two instruments: VIS, NIR
- ★ 1/3 of the Sky
- ★ 3-D Map of the Universe
- ★ Wide survey: 15,000 square degrees
- ★ Deep survey: 53 square degrees





The 15,000 deg.^{2} Euclid Wide Survey, the 53 deg.^{2} Euclid Deep Survey, and the 6 deep auxiliary fields (6.5 deg.^{2}) [Mollweide Celestial]

Euclid Wide Survey region of interest : 16 Kdeg.^{2} compliant with a 15 Kdeg.^{2} survey

Euclid Deep Fields : North=20 deg.^{2}, Fornax=10 deg.^{2}, South=23 deg.^{2}

Euclid deep auxiliary fields (GOODSN=0.5, AEGIS=1, COSMOS=2, VVDS=0.5, SXDX=2, CDFS=0.5 deg.^{2})

Background image: Euclid Consortium / Planck Collaboration / A. Mellinger

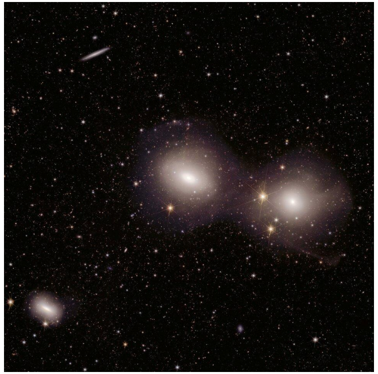
Euclid: Exploring the Dark Universe

Abel 2390

Messier 78

NGC 6744

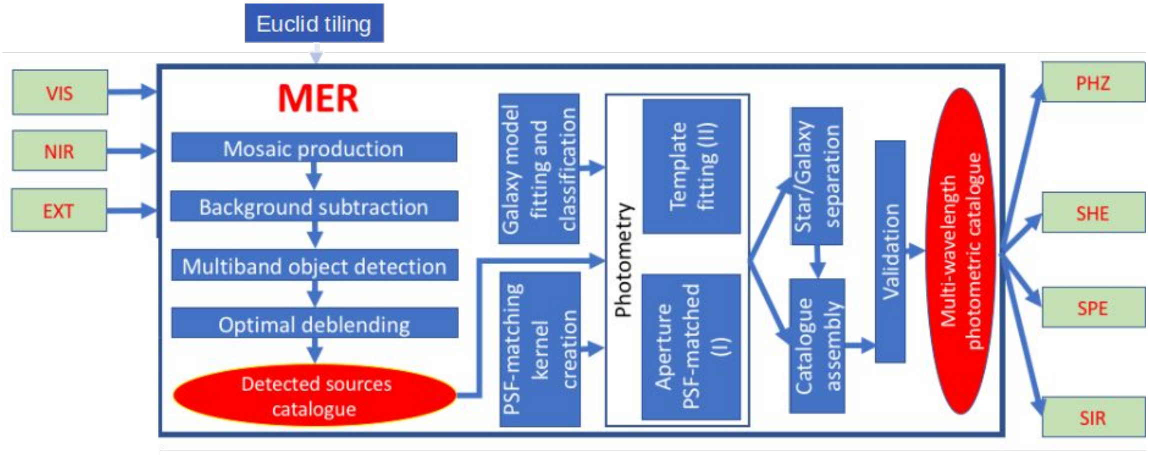
Abel 2764

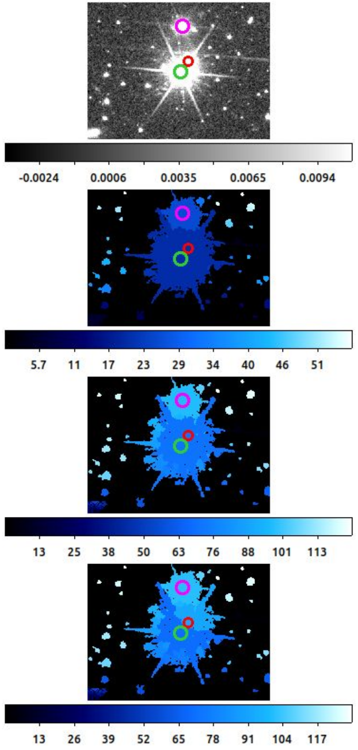


Dorado GG

Euclid's ERO Images

Euclid: Processing Pipeline and Deblending Issues





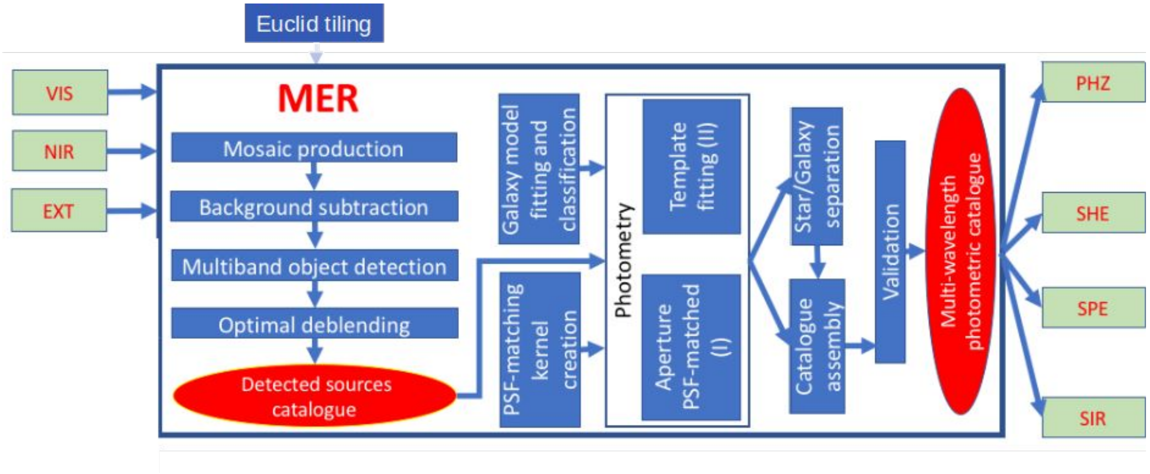
Challenging deblending issues to be addressed with ML:

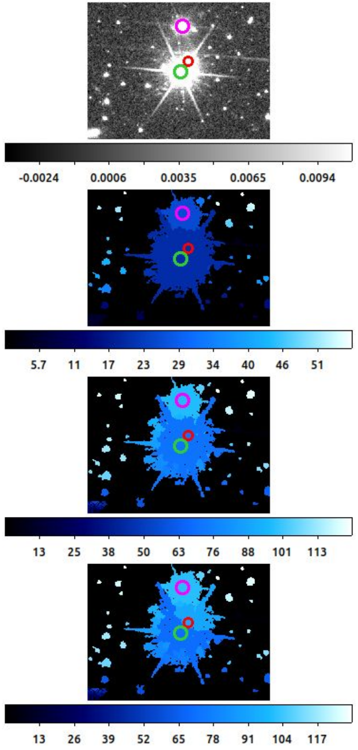
(1) Faint source + saturated star

(2) Faint source + bright/extended source

(3) Faint source + faint source

Euclid: Processing Pipeline and Deblending Issues





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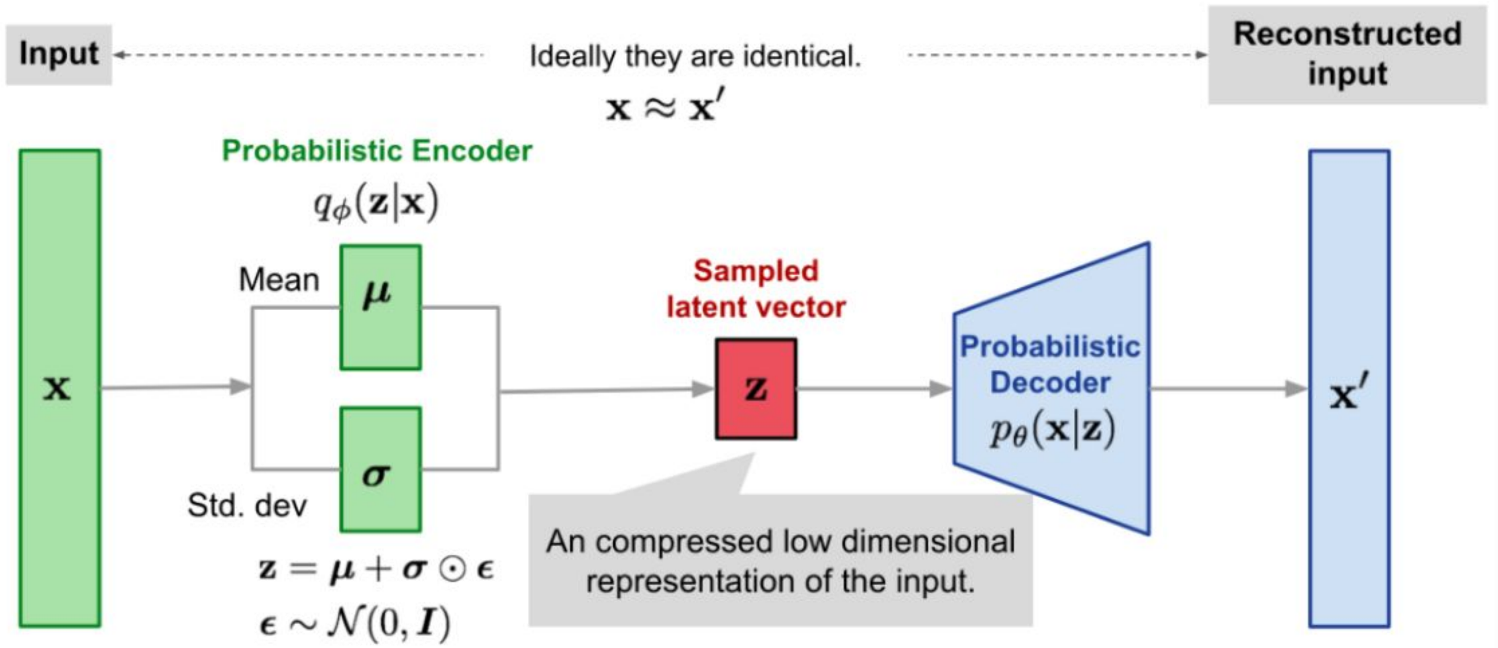
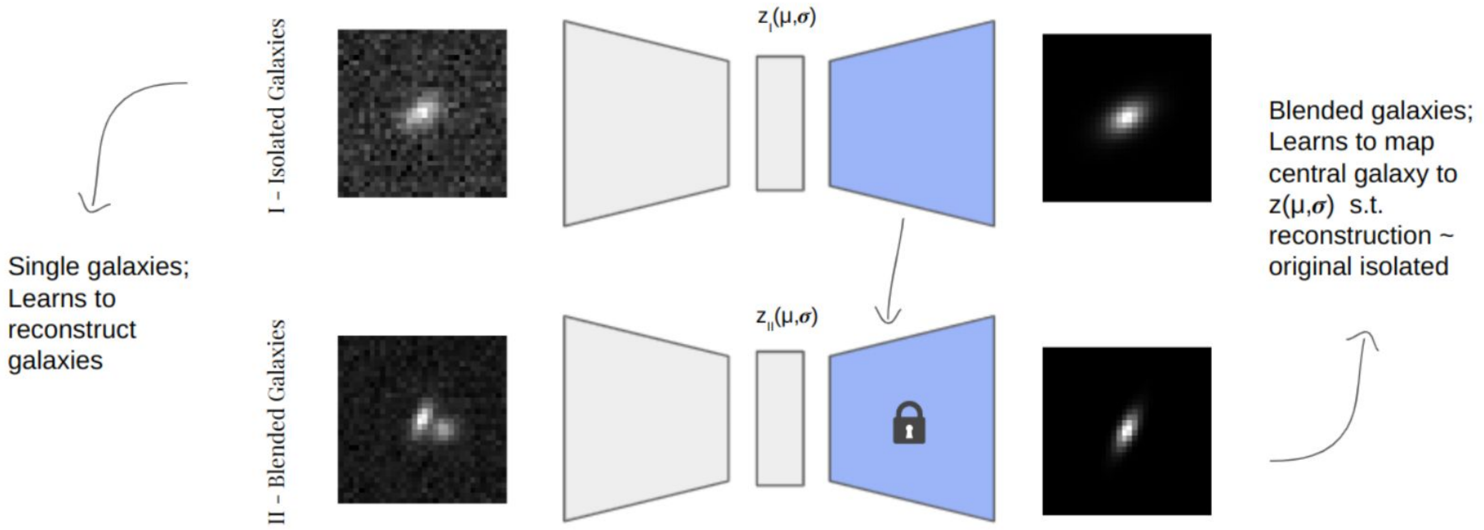
Deblending with ML: Variational Auto-Encoder (VAE)



Deblending with ML: Variational Auto-Encoder (VAE)



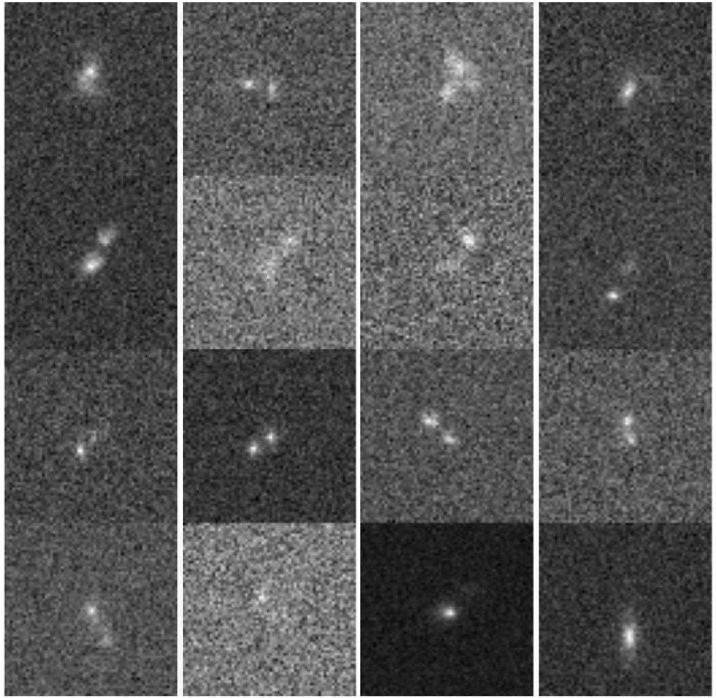
The input of the (second) VAE is a stamp with a blended pair of galaxies
The output is a reconstruction of the central galaxy in the blended pair

Deblending Simulations for training and testing sets

★ EUCLID Flagship simulation used as groundtruth:
  ○ Physical properties of galaxies
  ○ Fluxes for multiple bands (VIS, NIR, LSST, etc)
  ○ Morphological parameters

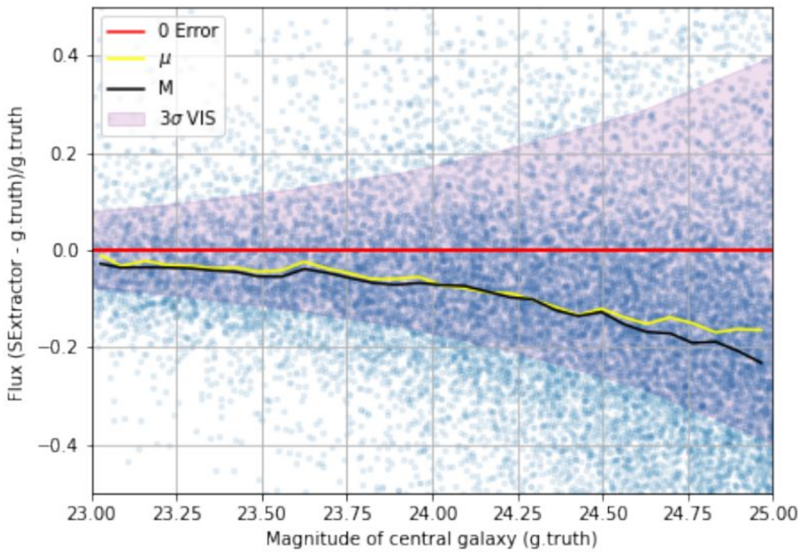
★ Generation of stamps with GalSim

★ Random degrees of overlapping between galaxies to simulate blending between two sources

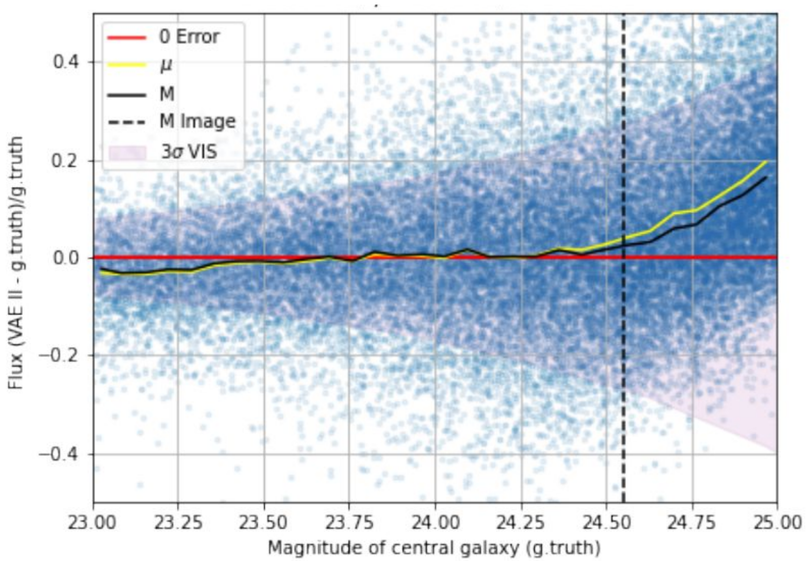


VAE Performance Results

★ Performance of the VAE deblender compared against SExtractor for faint sources in terms of df/f vs magnitude



SExtractor Deblending + Photometry



VAE

Conclusions & Perspectives

★ VAEs and equivalent ML algorithms offer **solid alternatives to replace some of the traditional and rigid data processing tools** used in astronomical pipelines, even when the training is carried out using simple simulations.

★ For the case of deblending, the next step is to recover **realistic morphologies** but this is difficult due to the subjectivity of the problem also at the level of photometry.

★ The access/generation to **calibration datasets** for every survey, that can be then used as ground-truth to retrain ML algorithms, would be extremely useful in the context of **transfer learning**.

★ **High-level astronomical processes**, such as deblending or photometry, require the optimal processing of the imaging data to yield accurate results. In that context, it would be ideal to find ways of making these processes **more robust to distortions**.

★ The **DR1 of Euclid** represents an ideal dataset to explore the potential of ML algorithms considering the millions of sources that will be detected.

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