Jean-Charles Cuillandre (CEA Paris-Saclay)

Stars in the eyes : the making of the first Euclid color images

SCIENCE & EXPLORATION

Euclid's first images: the dazzling edge of darkness

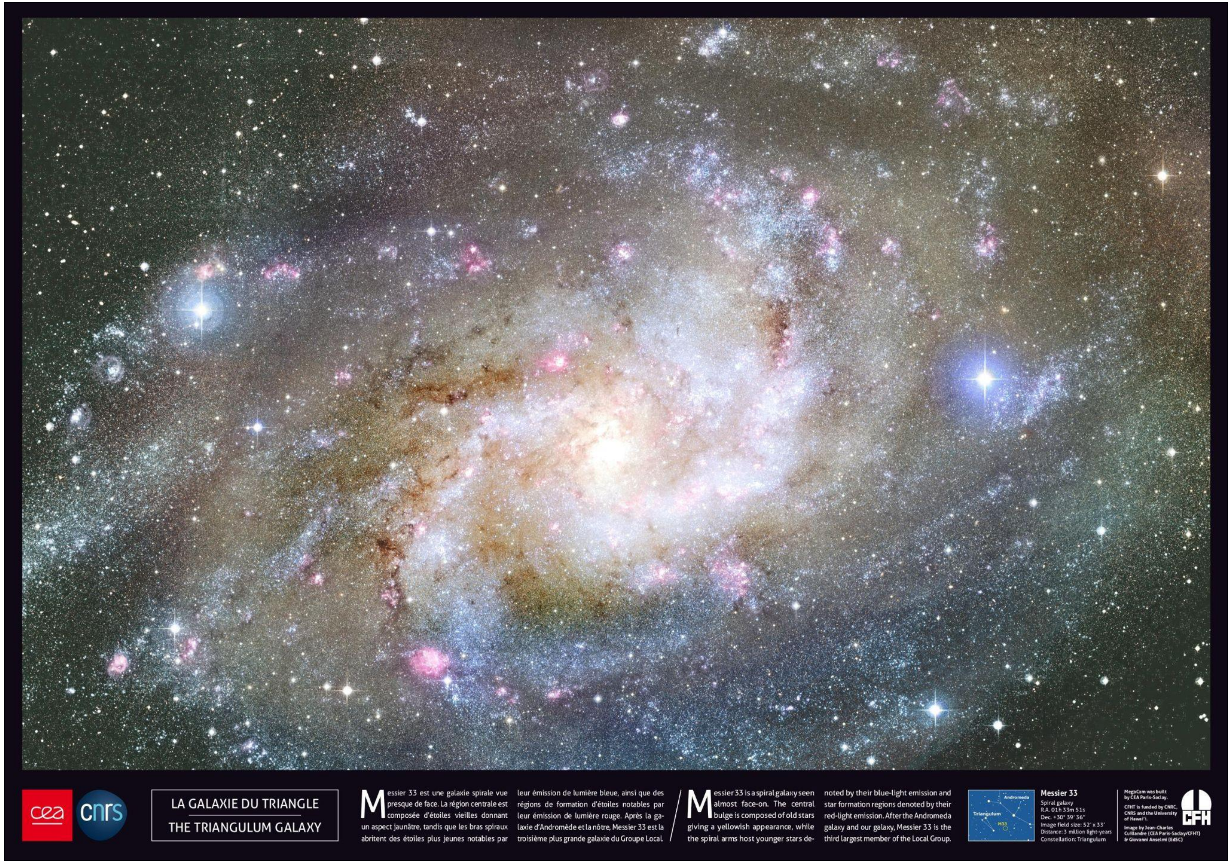
Today, ESA's Euclid space mission reveals its first full-colour images of the cosmos. Never before has a telescope been able to create such razor-sharp astronomical images across such a large patch of the sky, and looking so far into the distant Universe. These five images illustrate Euclid's full potential; they show that the telescope is ready to create the most extensive 3D map of the Universe yet, to uncover some of its hidden secrets.

Read more about Euclid's first images and download the individual images here

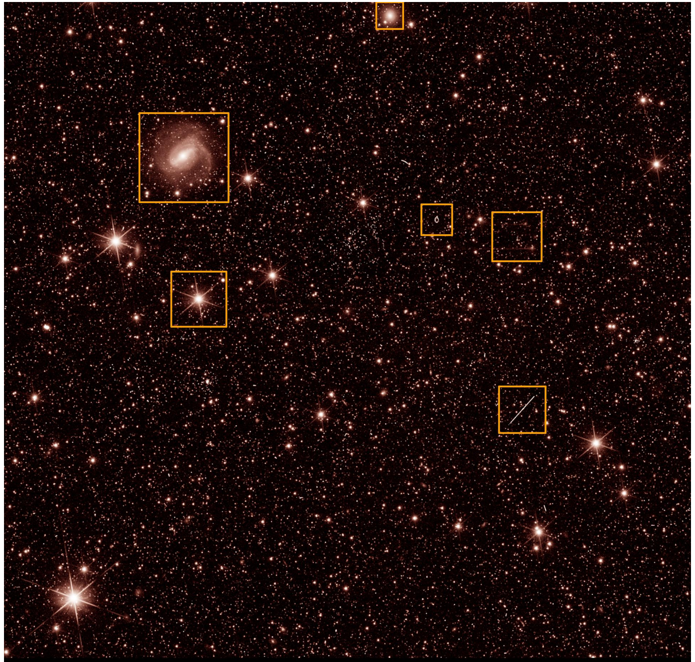
The Canada-France-Hawaii Telescope was a precursor in optical & near-infrared wide-field imaging to conduct large surveys for varied scientific communities

Hawaiian Starlight by CFH12K and MegaCam

CEA celebrating 20 years of MegaCam on CFHT



Euclid launch and first light



Early commissioning test image, NISP instrument

Euclid Early Release Observations media splash

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Euclid's first images: the dazzling edge of darkness

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Impact of the aesthetics of the cosmos

The ERO media splash showed how compelling visuals help convey complex concepts, such as hinting at Euclid's mission on dark matter and dark energy

OVERVIEW | ESA MEMBER STATES

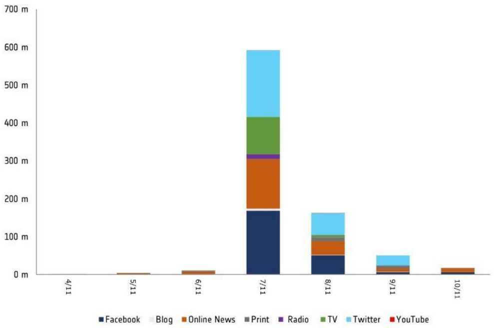
In terms of traditional media within ESA member states, the gross reach amounted to an impressive 342.5 million for the Euclid first images. Traditional media visibility in ESA member states was particularly strong in the UK (thanks in large part to extensive BBC coverage across various channels), France, Spain and Germany which accounted for most of the coverage.

Social media represented 60% of all visibility in ESA member states – driven by strong visibility on Facebook and Twitter. Though not a surprise given the highly visual and shareable assets that were being released. Interesting, and positive, to see ESA accounts not featured too prominently in terms of the reach achieved.

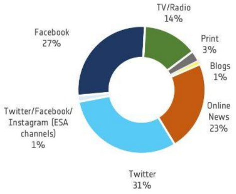
Online news was the most visible traditional media format, representing 23% of all visibility in ESA member states. Followed by TV & Radio with 14%. The peak in coverage coming exactly at 14:15, when the under-embargo ended, indicates the success that sending information and assets to media beforehand had in relation to the impact that was generated.

	Traditional media		Social media	
	Gross Reach	Volume	Gross Reach	Volume
Visibility in ESA Member States	342.5 M	3.1 K	506 M	1.7 K
Overall visibility	574.2 M	5.7 K	2.07 Bn	4.2 K

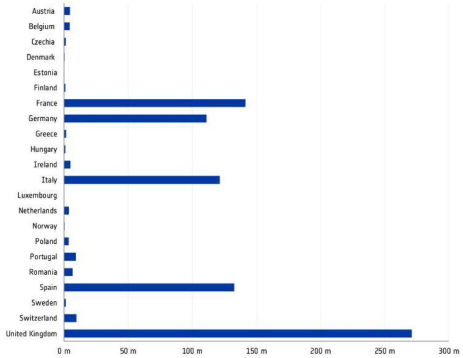
Visibility Trend
Visibility by date and by channel (Gross Reach)



Media split
Visibility by channel (Gross Reach)



Markets
Visibility by country* (Gross Reach)

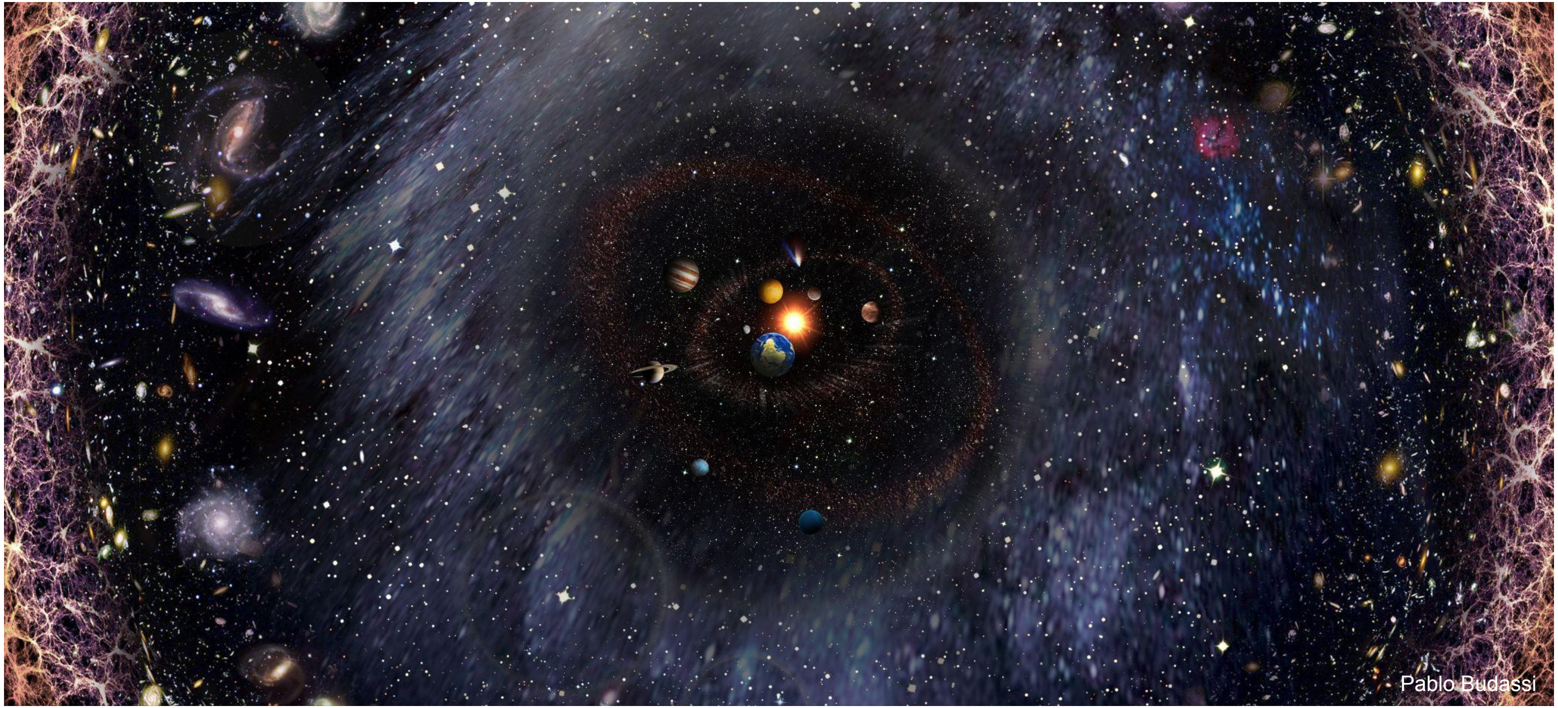


Euclid first images

*Instagram cannot segment by country

The wow factor of large astronomical objects

ESA's goal with the EROs : explore the aesthetics of the cosmos through diverse science validation programs on extended sources filling the Euclid field-of-view

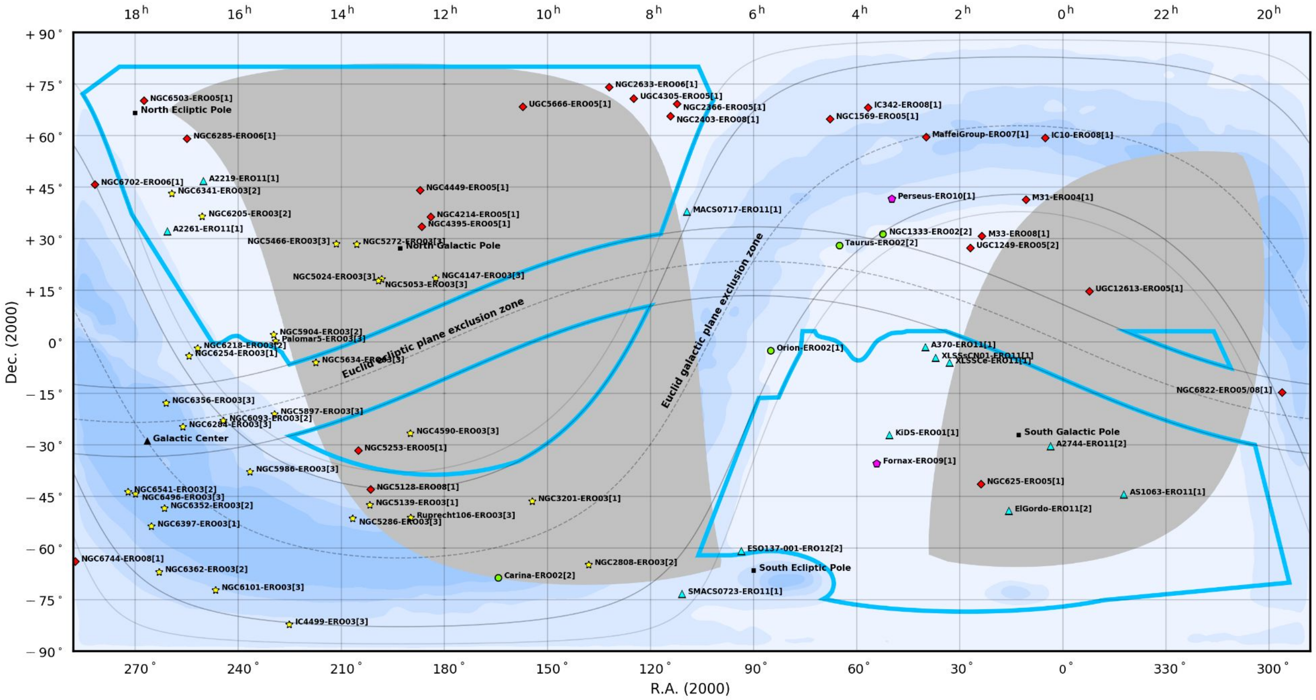


The ESA Euclid Early Release Observations call

The spring 2023 call for proposal to the Euclid Collaboration (Euclid Consortium + Independent Legacy Scientists) had a pressure factor of ~3 in time (12 proposals)

- Selection of targets with strong communications/outreach and science merit highlighting Euclid's capabilities for both cosmology and legacy science
- Communications & outreach merit took precedence over science merit
- Observations were not limited to within the nominal Euclid survey area
- Total Euclid observing time for the whole ERO program : 24 hours
- Use of the standard observing block (ROS) of 70 minutes, covering a field of 0.7x0.7 deg2
- 4 dithers (different pointings) in : VIS, NISP spectroscopy, NISP-Y, NISP-J, NISP-H
- Programmed along the (re)commissioning and performance verification phases

ERO technical feasibility : visibility of all proposed targets



Euclid PV phase : visibility for a July 10 2023 launch of the 12 ERO proposals (Target - Program [Internal Priority])

Sky not accessible during the performance validation phase

Wide Survey region of interest (16 Kdeg^2)

Galactic : Nebula, Globular cluster

Extragalactic : Nearby galaxy, Nearby cluster of galaxies, Cosmology field (with cluster)

Six programs from the Galaxy out to a z=0.23 cluster

The chosen narrative of the ERO aimed at exploring the cosmos from our direct neighborhood out to the distant Universe, culminating with a plethora of galaxies

- A first glance at free-floating baby Jupiters with Euclid
  Program Scientist : Eduardo Martín (Instituto de Astrofísica de Canarias)

- Euclid view of Milky Way globular clusters
  Program Scientist : Davide Massari (INAF-OAS Bologna)

- A Euclid showcase of nearby galaxies
  Program Scientist : Leslie Hunt (INAF-AO Arcetri, Firenze)

- The Fornax galaxy cluster & Dorado group of galaxies seen with Euclid
  Program Scientist : Ariane Lançon (Observatoire de Strasbourg)

- The Perseus cluster of galaxies
  Program Scientist : J.-C. Cuillandre (CEA Paris-Saclay)

- A Glimpse Into Euclid's Universe Through a Giant Magnifying Lens
  Program Scientist : Hakim Atek (Institut d'Astrophysique de Paris)

Diffuse emissions with Euclid

Euclid's stringent requirements on the quality of the PSF led to an optical design that de facto guarantees spectacular low surface brightness sensitivity

ERO pipeline : from raw data to science-ready catalogs

The ERO pipeline is based on the Elixir C code pixel processing software I developed for CFHT's optical & near-infrared mosaic cameras, tightly coupled to E. Bertin's AstrOmatic rich suite, along powerful Python layers and packages from the community (e.g. Astrometry.net, DeepCR), and from ERO scientists (e.g. NISP persistence)

VIS ERO processing

- LE1 to LE1-FH enriching + previews + db
- Detrending : Mask/Overscan/Bias/Flat-field
- High energy particle hits healing
- Low-flux non-linearity correction
- Astrometric calibration
- Re-sampling*, stacking (Flattened & LSB)
- PSF modelling
- Photometric extraction
- Data quality control and validation

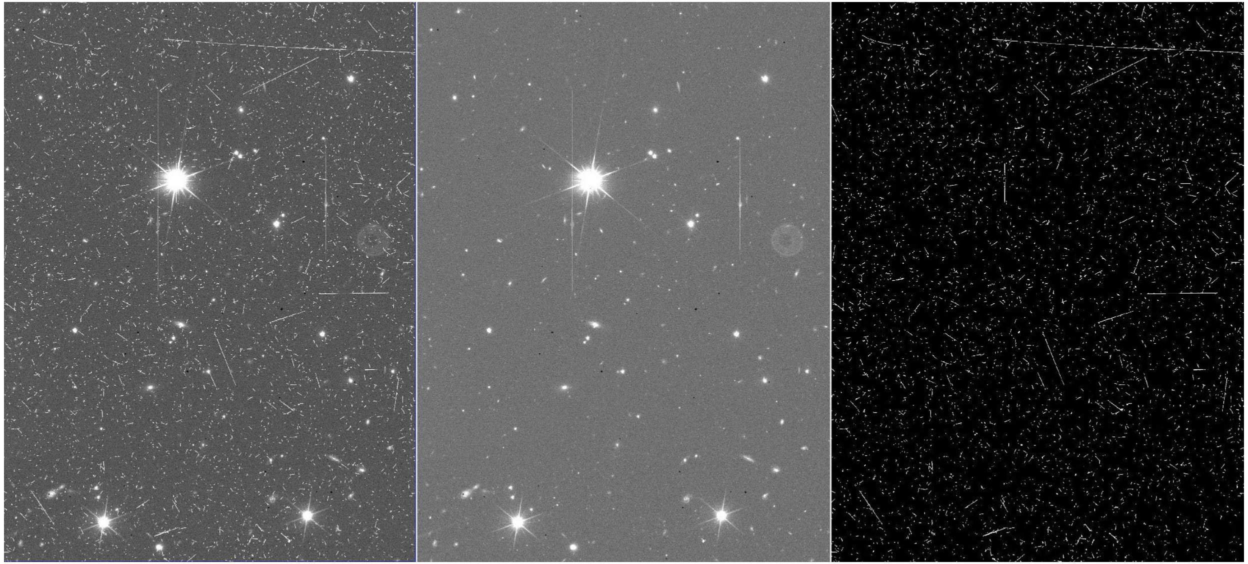
NISP ERO processing

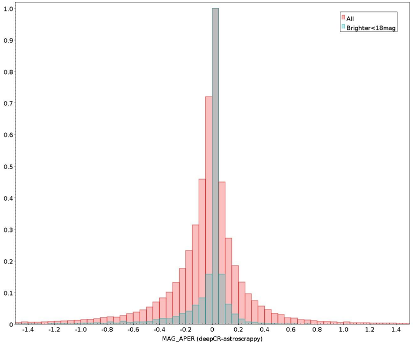
- LE1 to LE1-FH enriching + previews + db
- Persistence removal
- Detrending : Mask/Reference/Dark/Flat-field
- Reset level correction
- Astrometric calibration
- Re-sampling* for stacking (Flattened & LSB)
- PSF modelling
- Photometric extraction
- Data quality control and validation

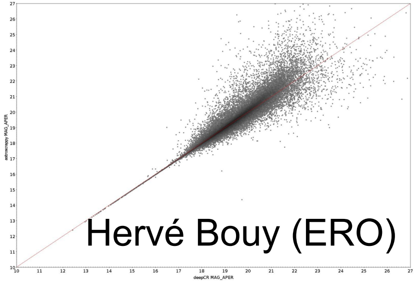
**Lanczosc3 for VIS, Bilinear for NISP*

VIS : healing high energy particle hits with DeepCR

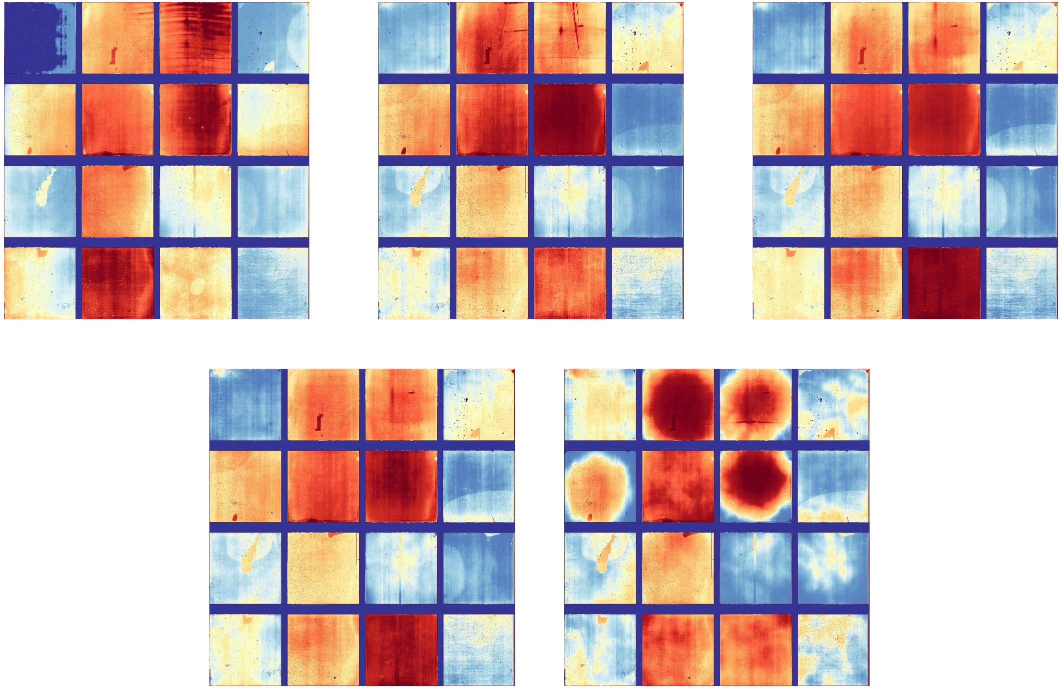
DeepCR (2019) is a Python ML based tool trained on data from HST's CCD mosaic cameras. A VIS image is processed in less than 2 minutes on a GPU RTX2060. The key in-painting fills the CR affected locations, preserving photometry & shape precisely.



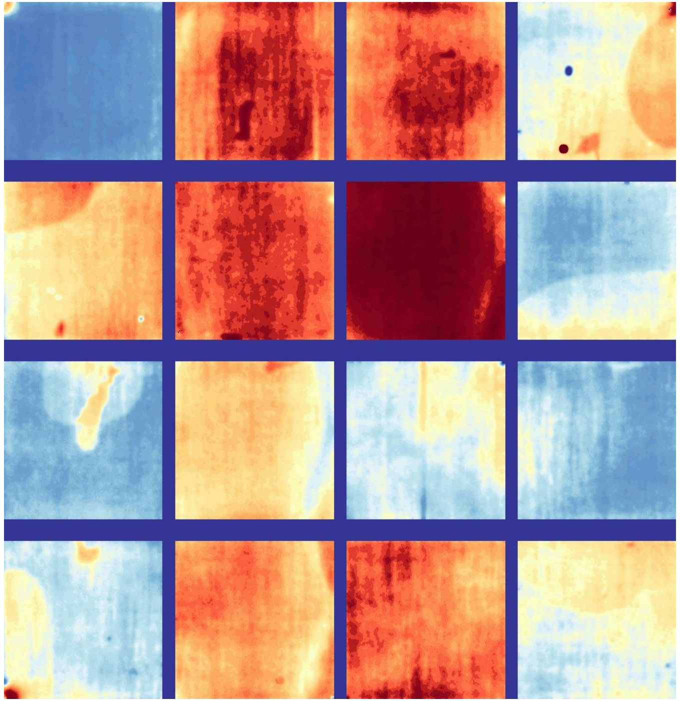




VIS & NISP flat-fields : zodiacal light background + LEDs

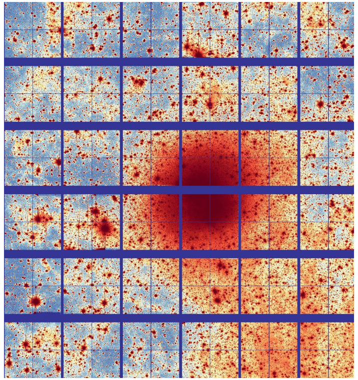


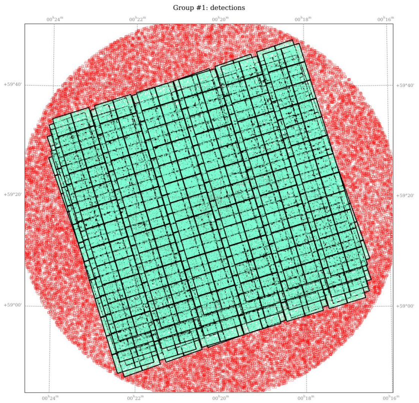
NISP LED flat-fields (A,B,C,D,E)
flattened for small scales recovery only

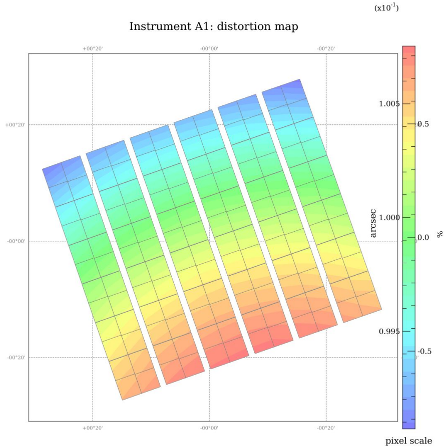


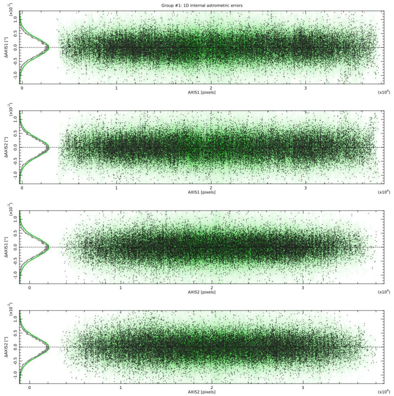
NISP zodi Y-band flat-field, pre
smoothing, for large scales recovery only

VIS astrometry = Astrometry.net + AstrOmatic scamp

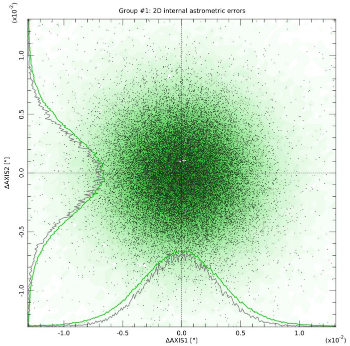


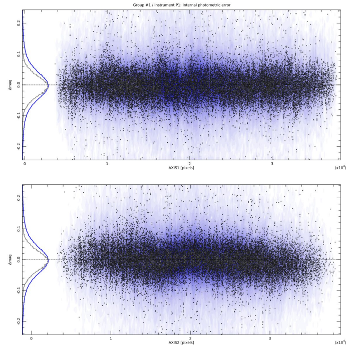






3 mas on
ERO IC10

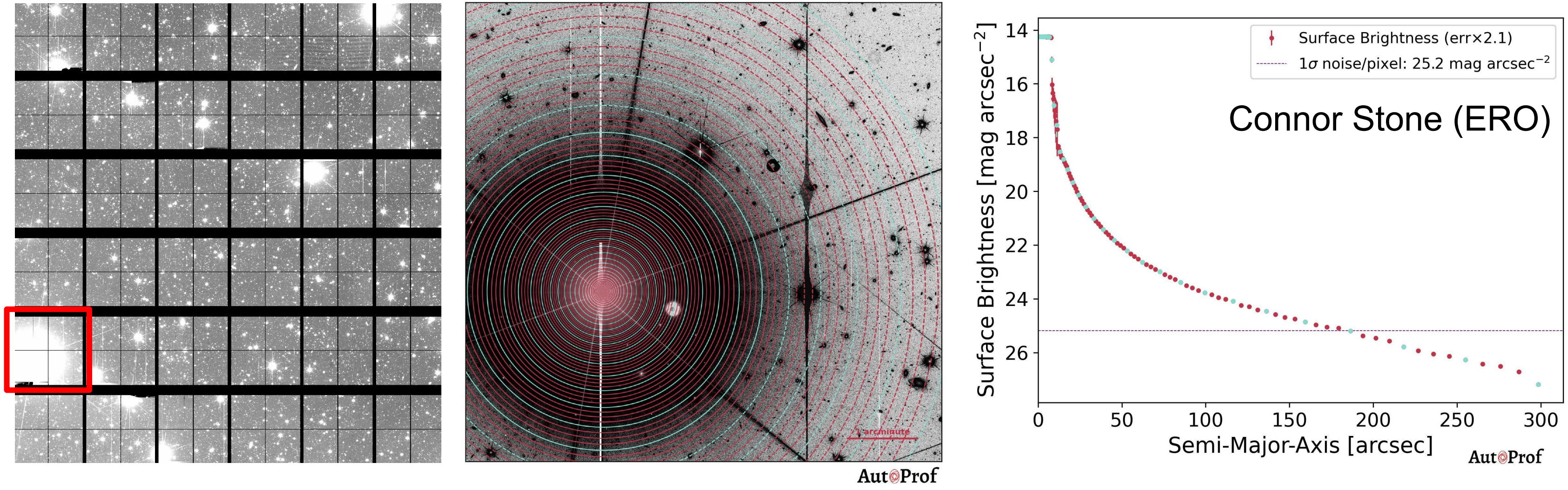




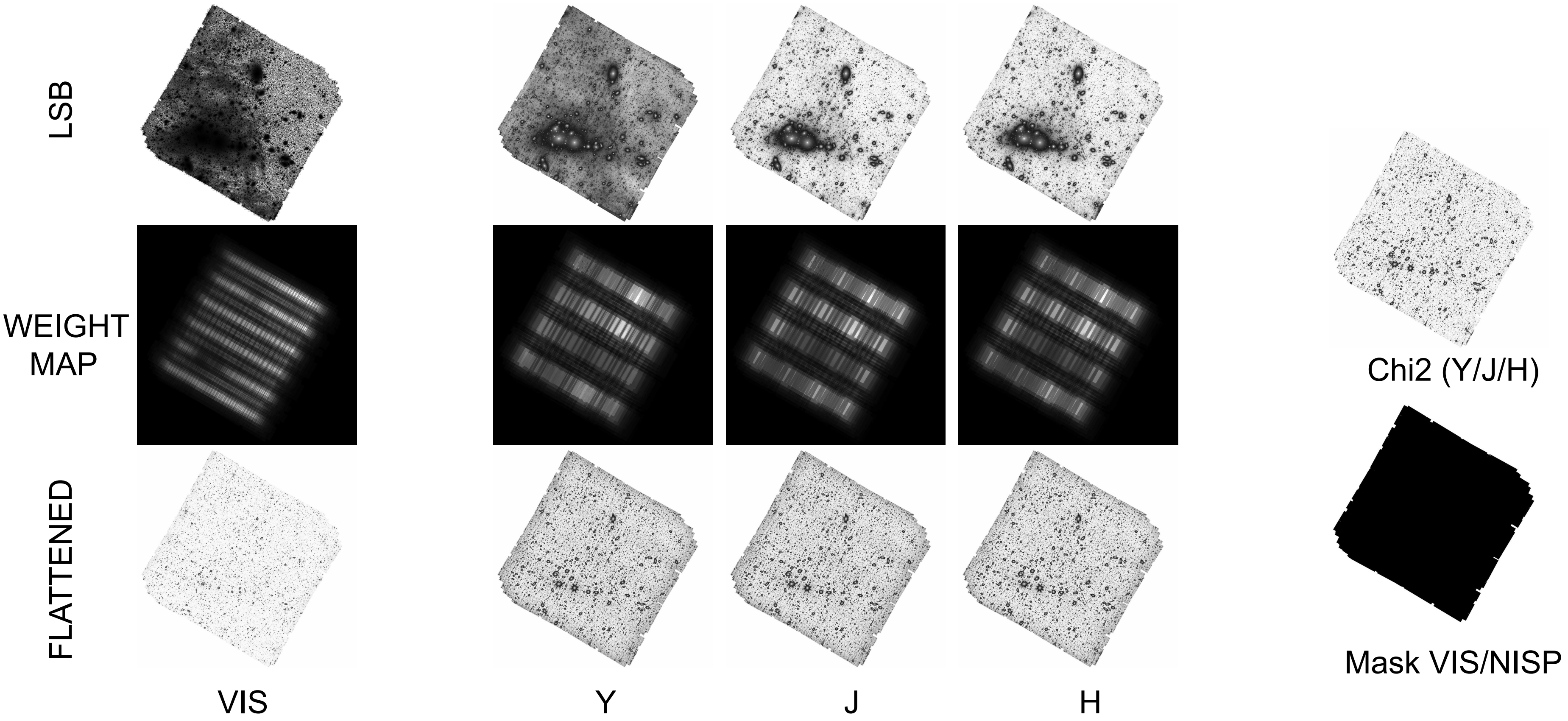
With key support from Dustin Lang, Emmanuel Bertin, and Mischa Schirmer

VIS extended PSF

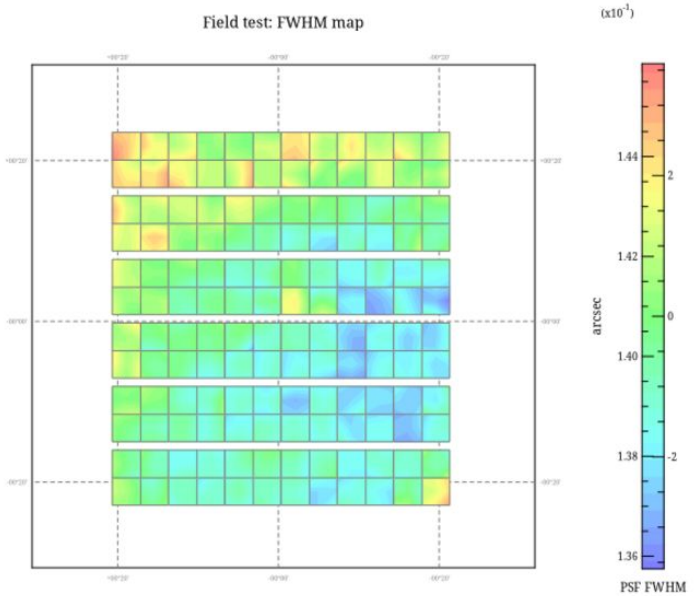
A 4.5 VIS AB magnitude star happened to fall within the FOV of a commissioning phase pointing, offering the opportunity to explore the extended PSF (= extended emission). The signature ends at a 5′ radius at 27.5 mag. per square arcsecond (!). The actual true loss on faint sources in the FOV due to the contamination is ~2% vs the 10% estimated during the technical evaluation (c.f. 2022 Wide paper Fig.4). Using increasingly fainter stars, the flux present in the extended PSF vs the core can be derived to characterize this remarkable optical realization.



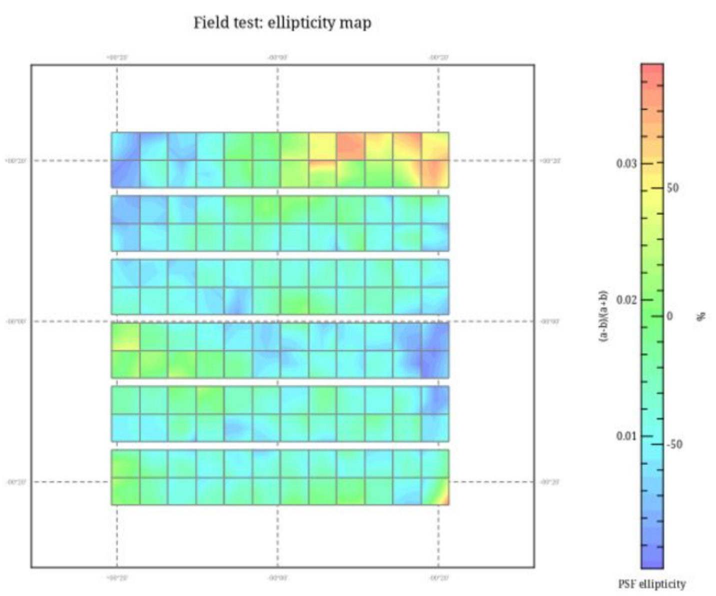
ERO pipeline advanced imaging products (stacks)



PSF modeling & photometric extraction by AstrOmatic



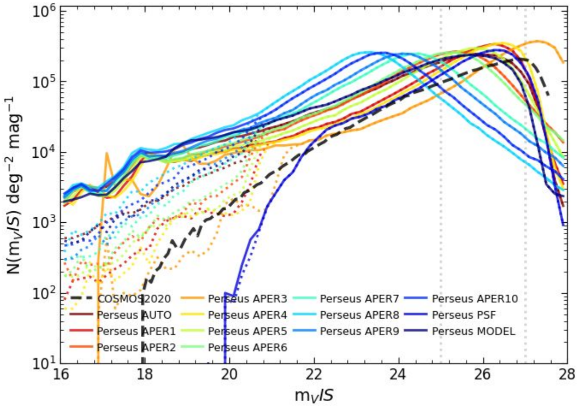
0.14'' FWHM

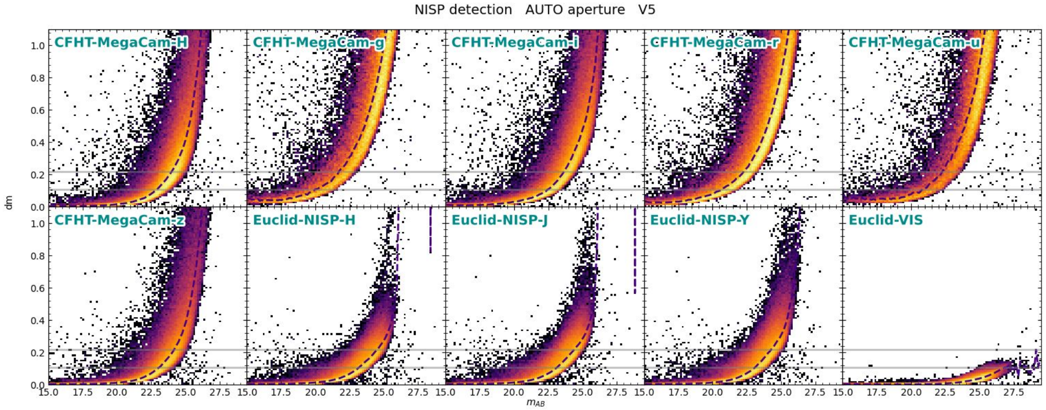


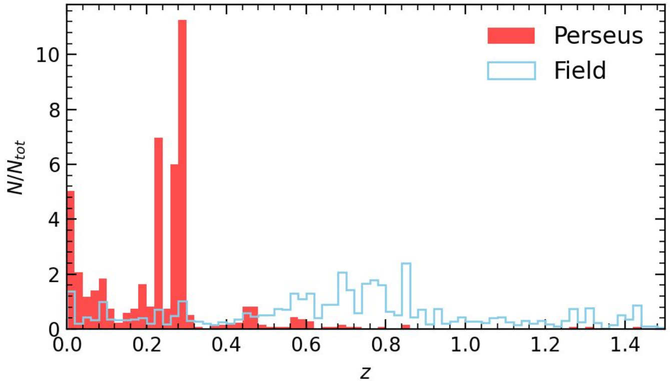
A PSF model across the field-of-view is produced with PSFex at high resolution with optimal settings for undersampled data, and coupled to Source Extractor with matched photometric extraction for NISP Y,J,H bands using a Chi2 detection image (Stacks: VIS=0.16'' NISP=0.49'')

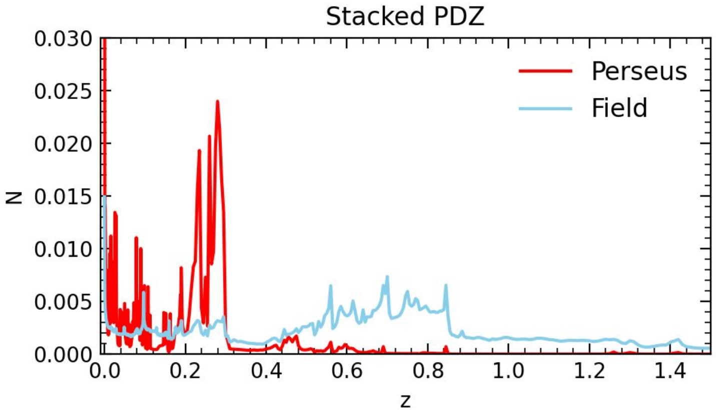
With kind support from Emmanuel Bertin

Performance validation & photo-z by M. Bolzonella



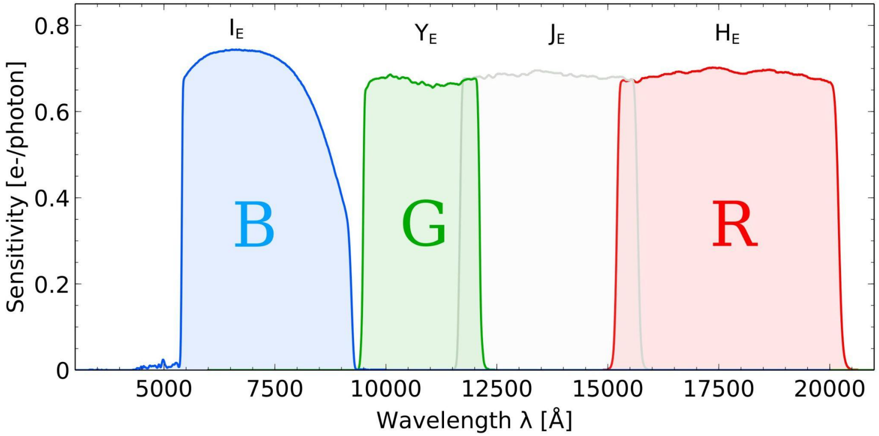


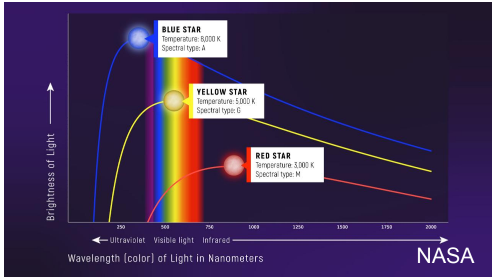




The Euclid color palette

Casting three out of the four colors captured by Euclid into Red-Green-Blue (RGB) images leads to a unique color nuance anchored in astrophysics





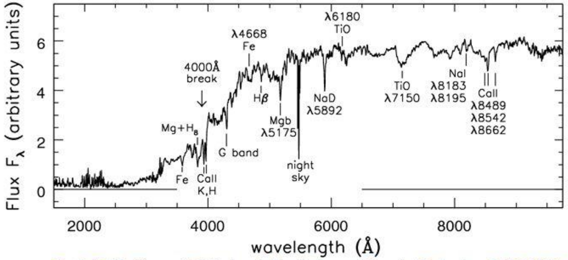
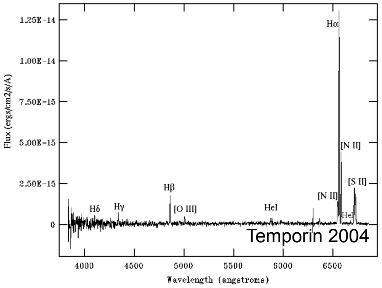
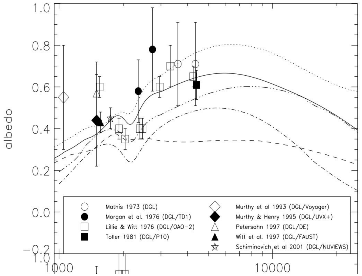
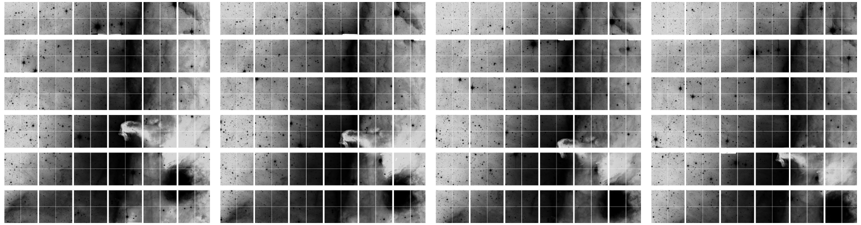


Fig 6.17 (A. Kinney) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

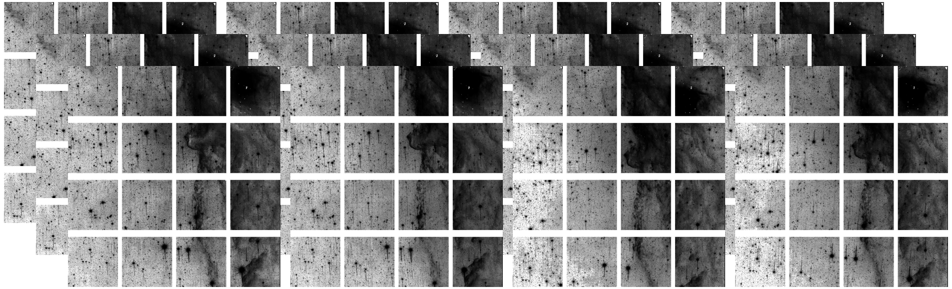




The Horsehead nebula by Euclid - 1



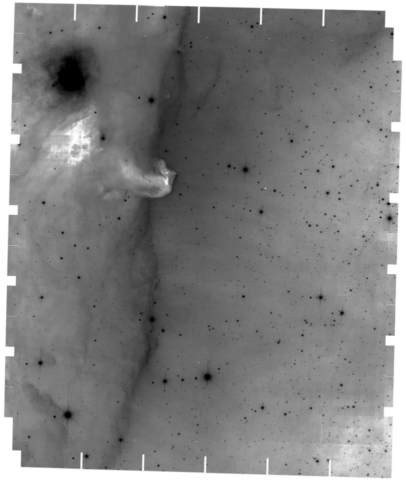
ROS Pos1 ROS Pos2 ROS Pos3 ROS Pos4



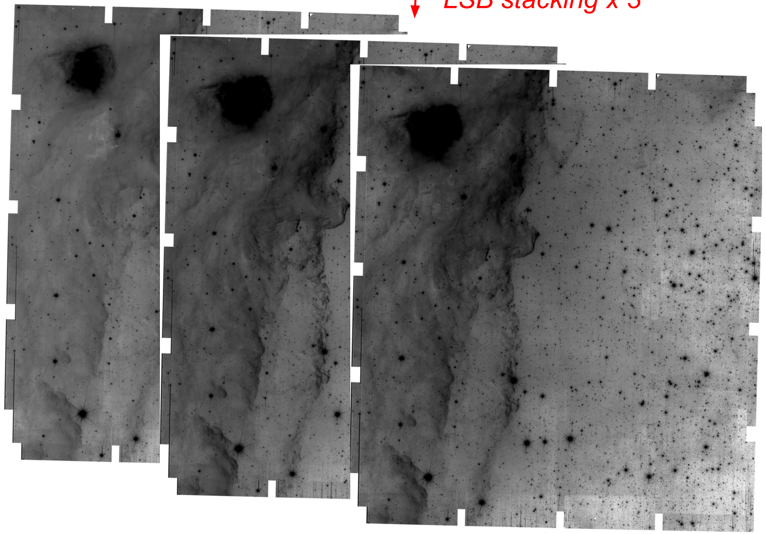
↓ *LSB stacking*

↓ *LSB stacking x 3*

VIS

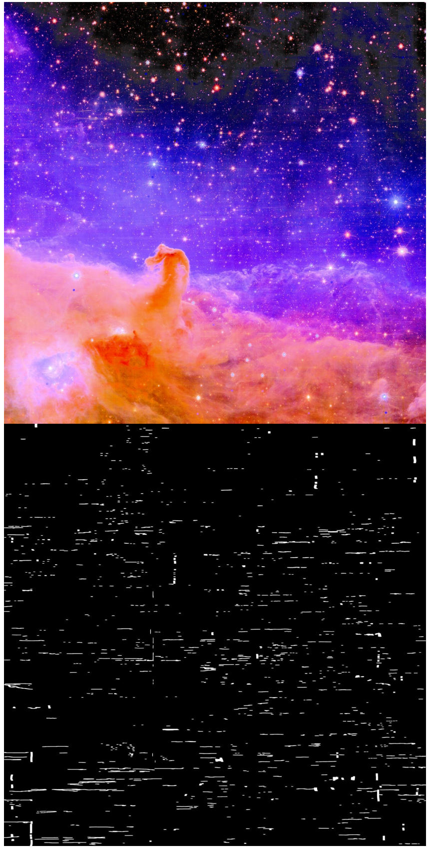


NISP Y,J,H



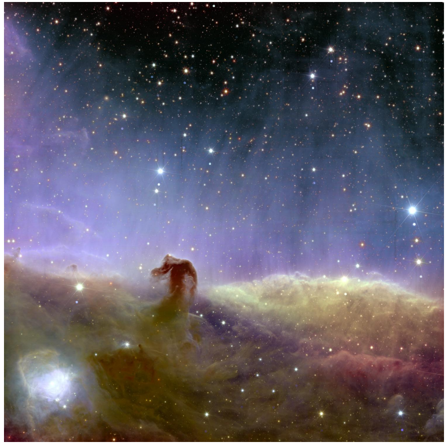
The Horsehead nebula by Euclid - 2

RGB with NISP persistence



In-Painting

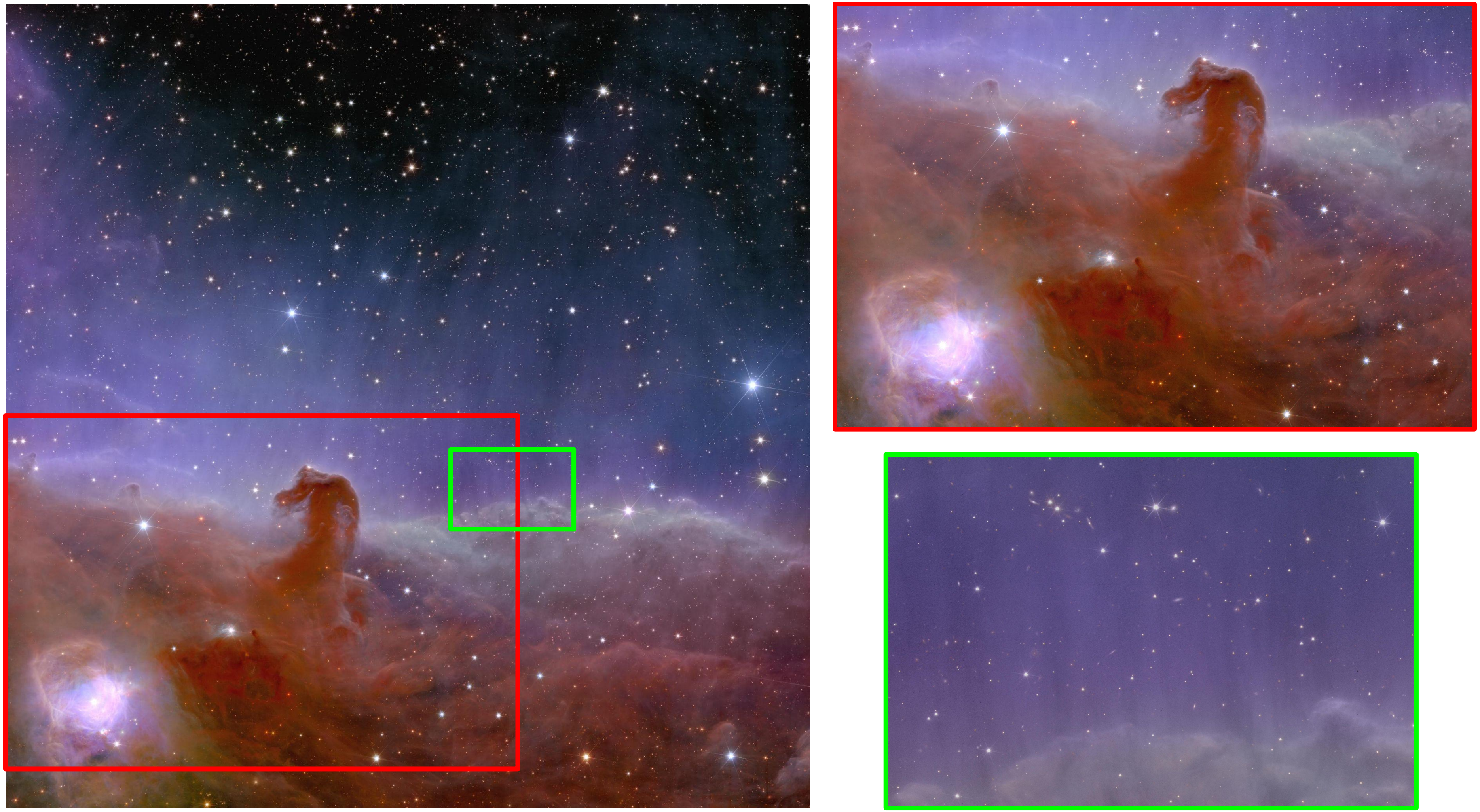
The Horsehead nebula by Euclid - 3

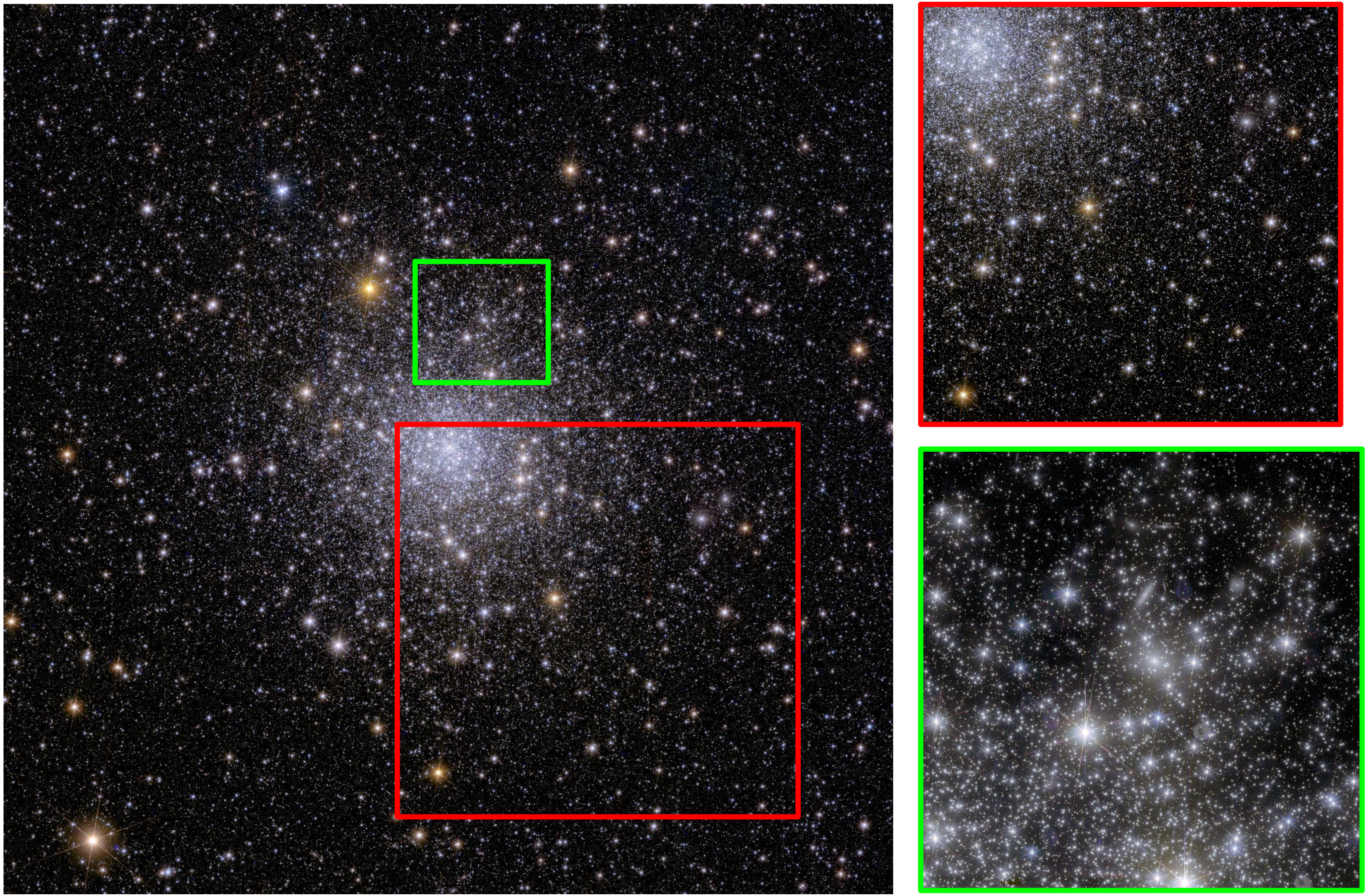


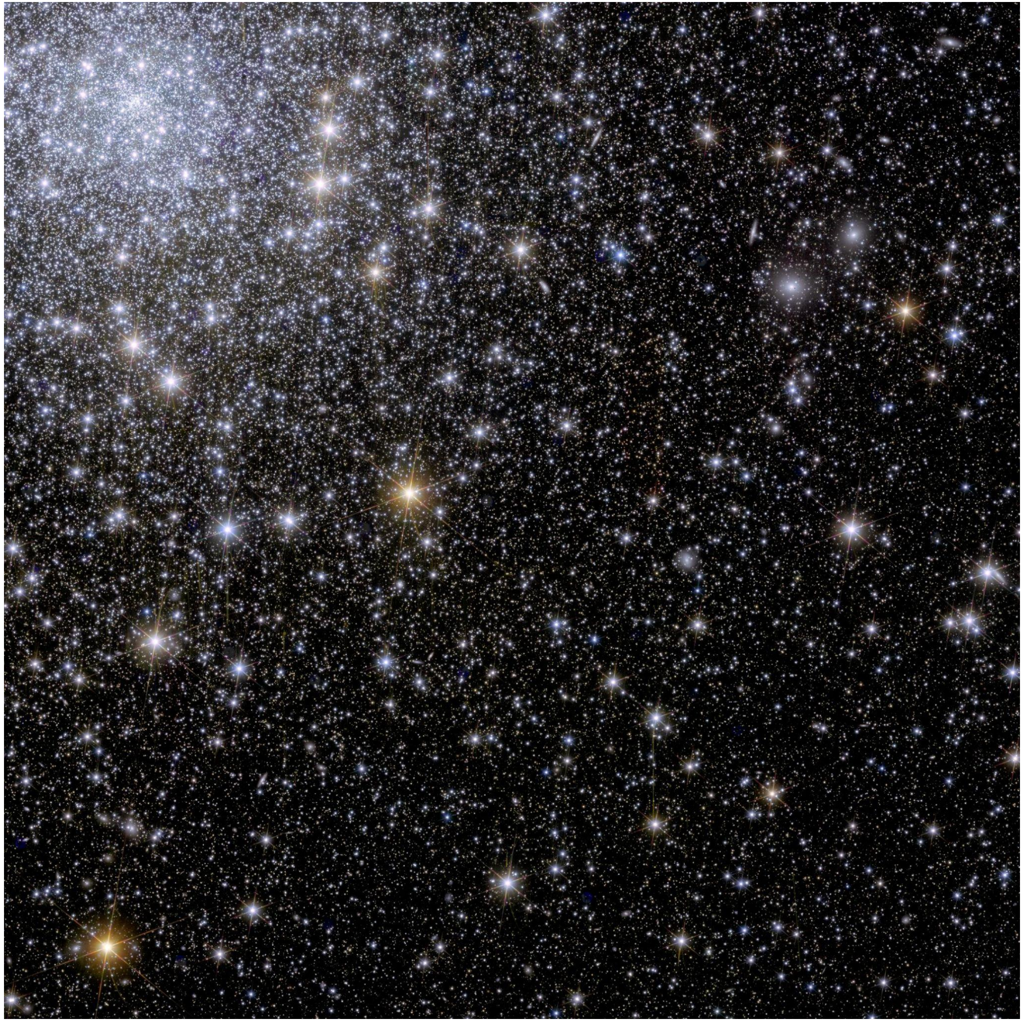
Giovanni Anselmi's optimization (PhotoShop)

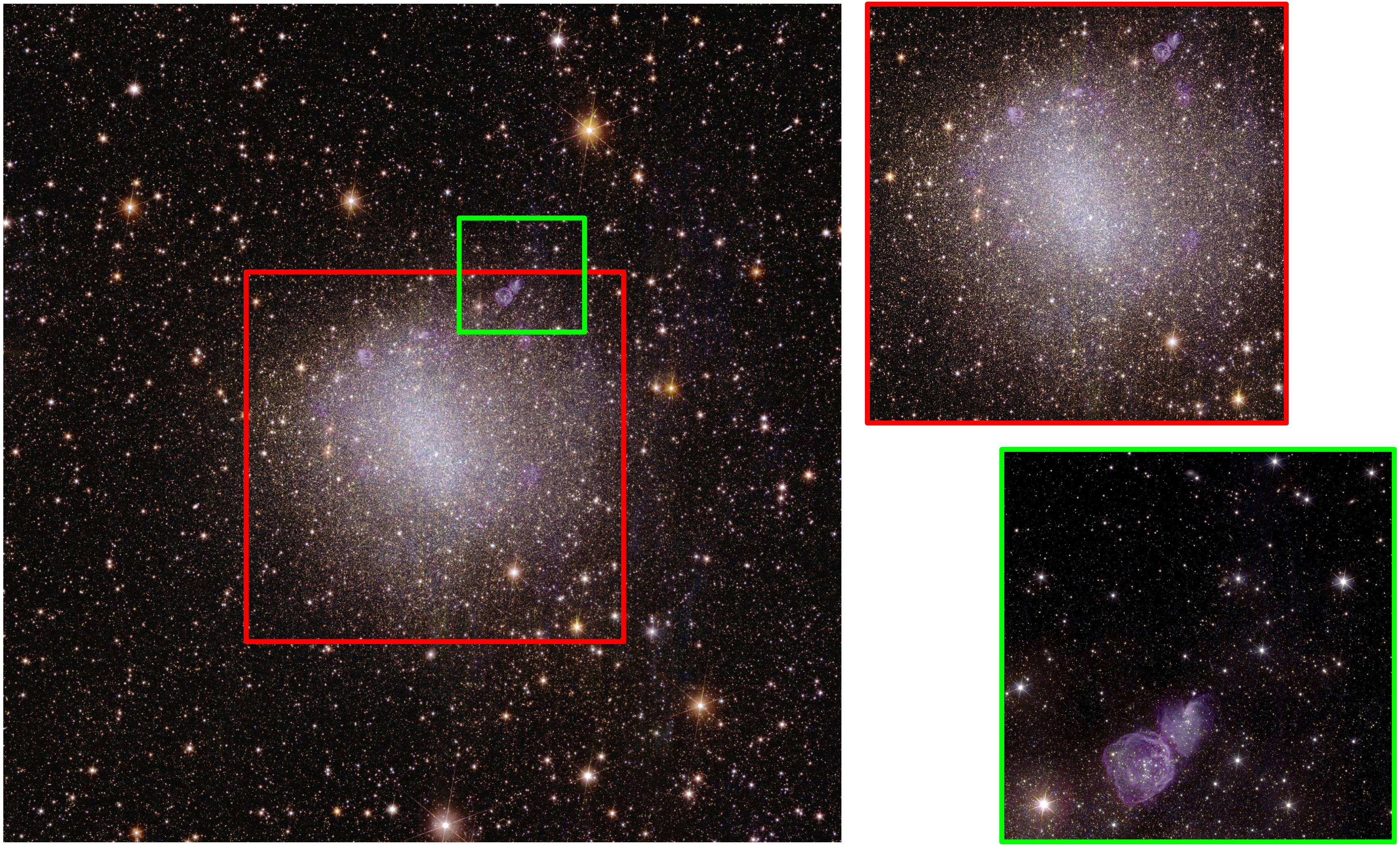
Various blends with the original RGB for test screening

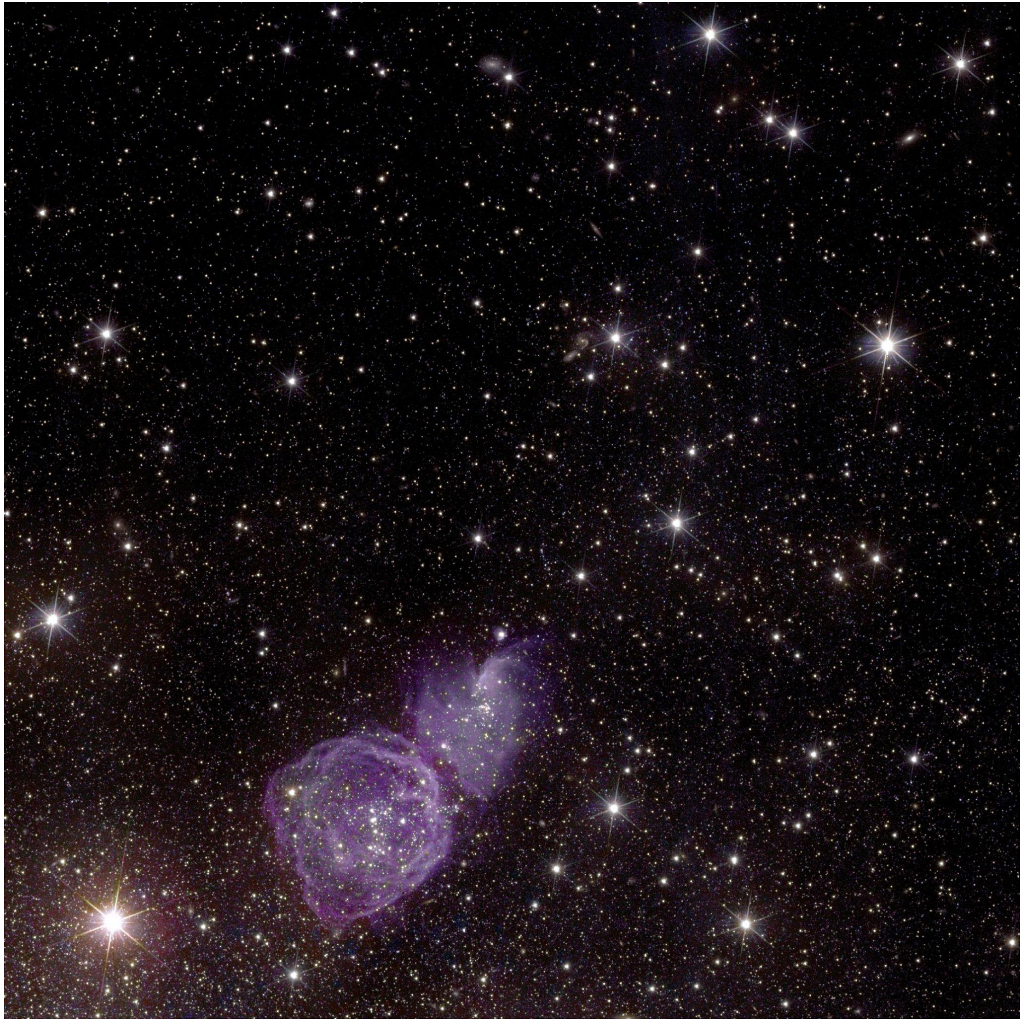
Final selection

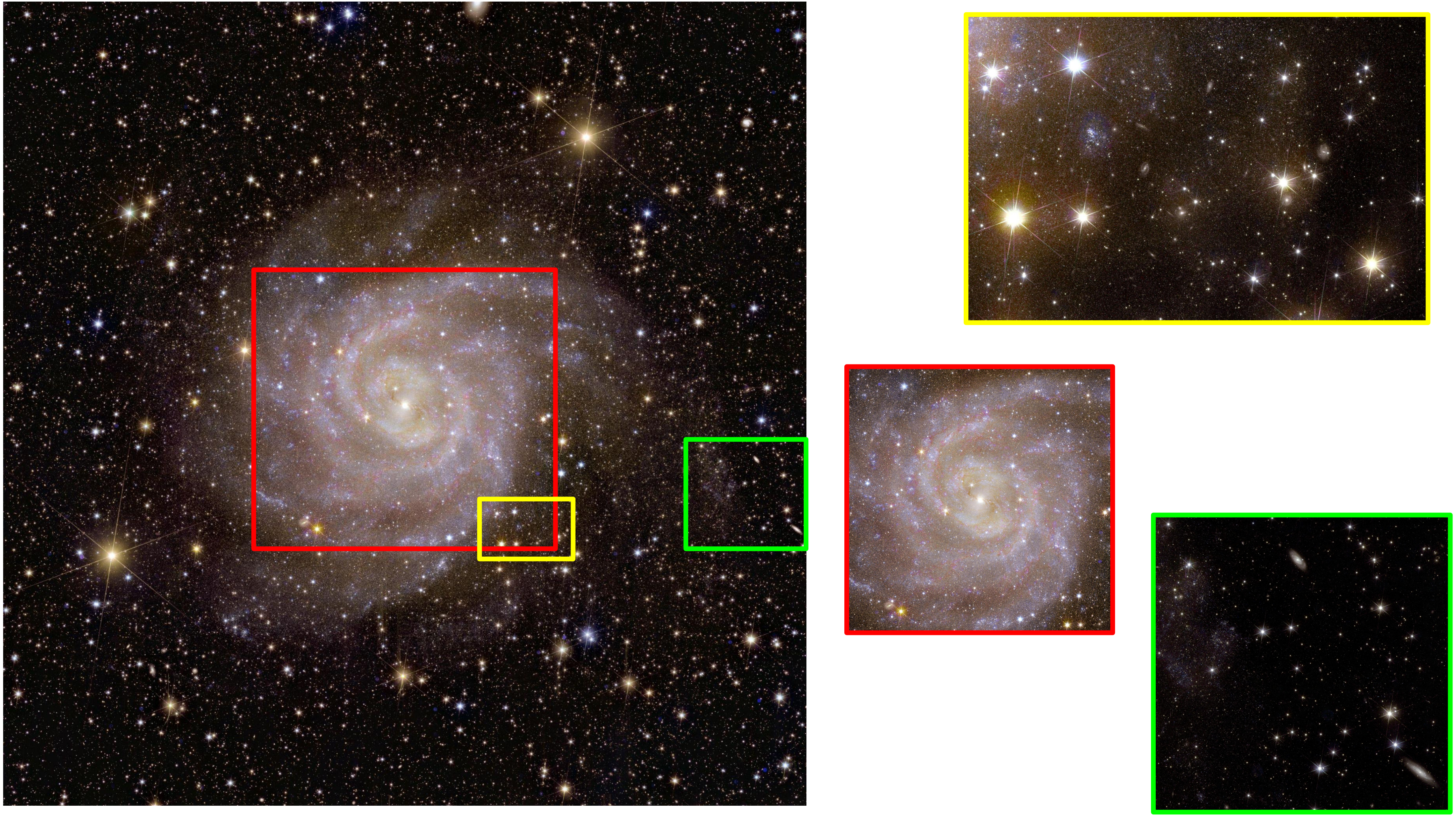


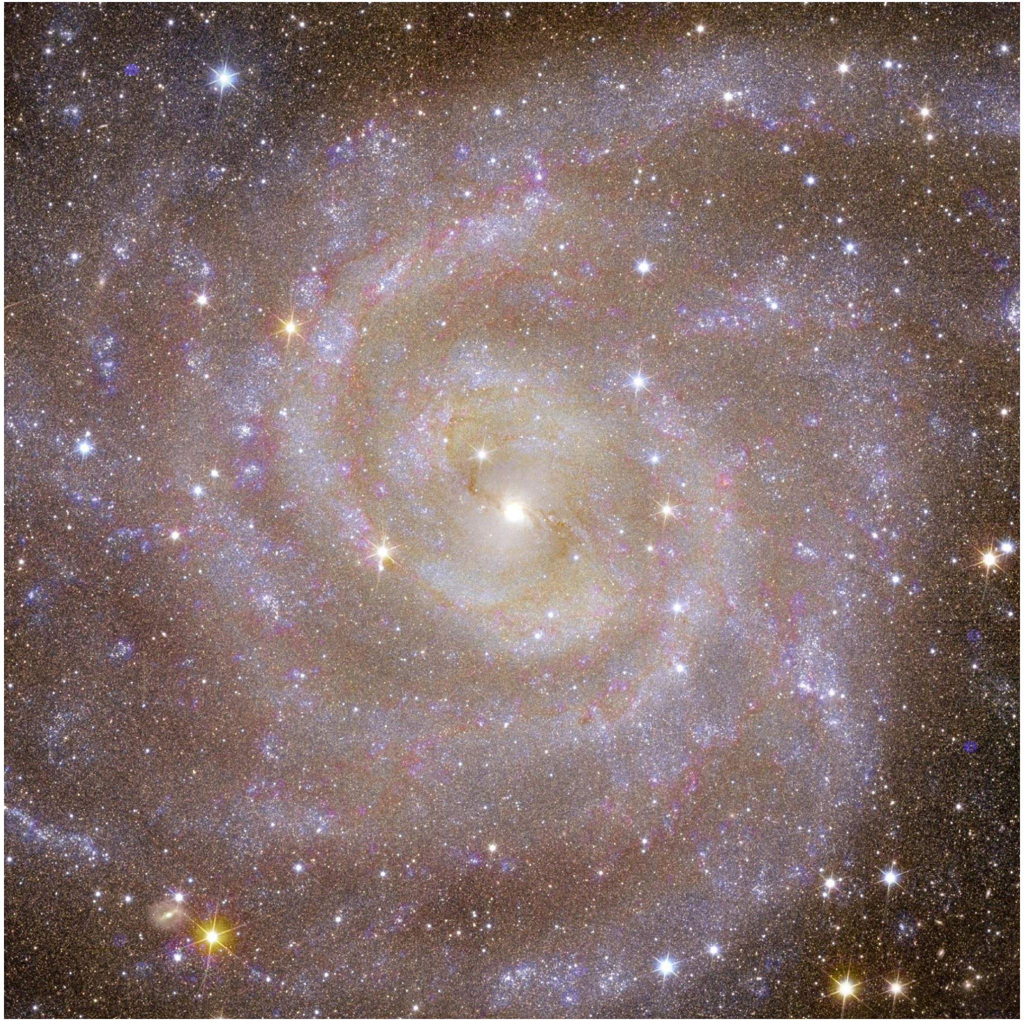


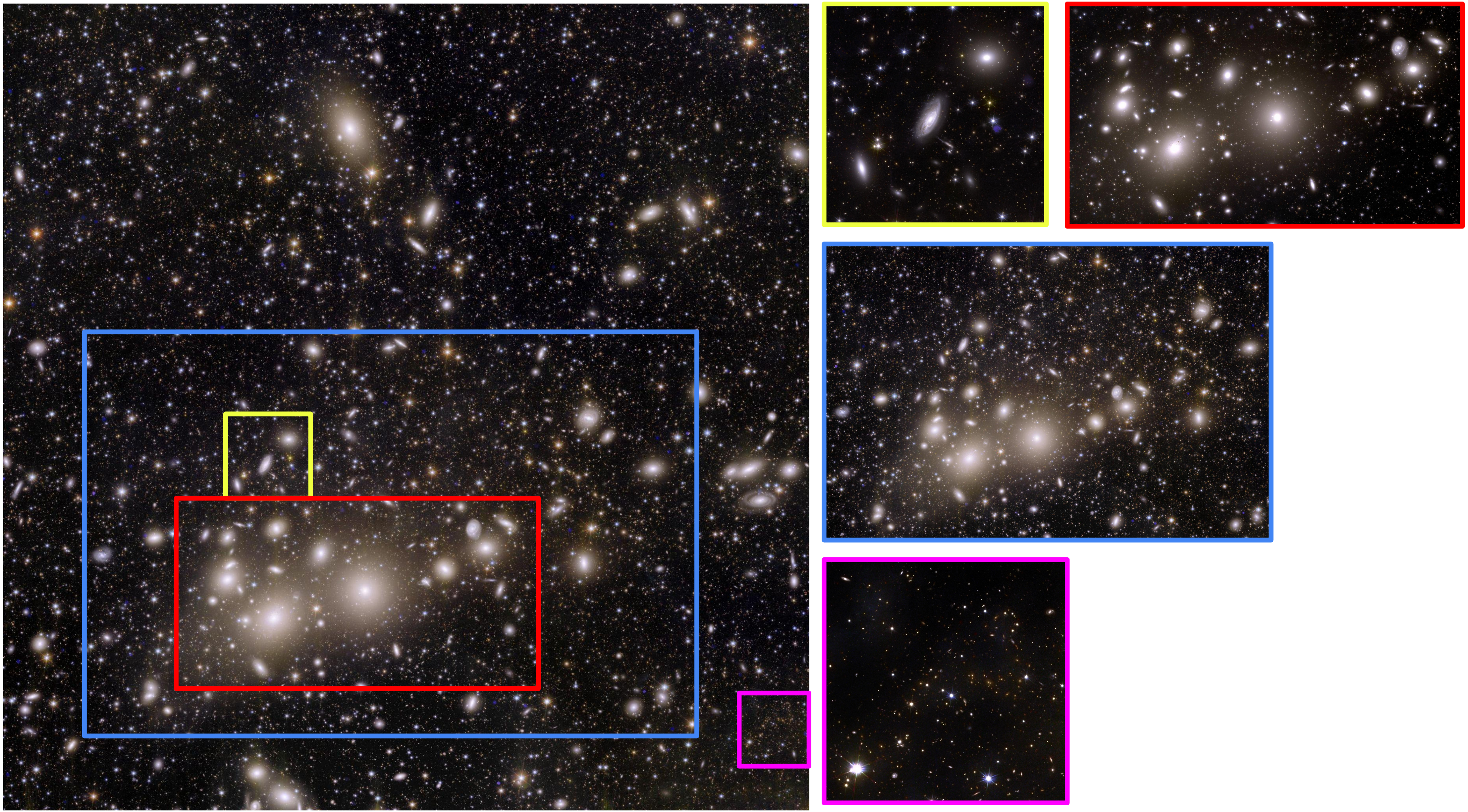


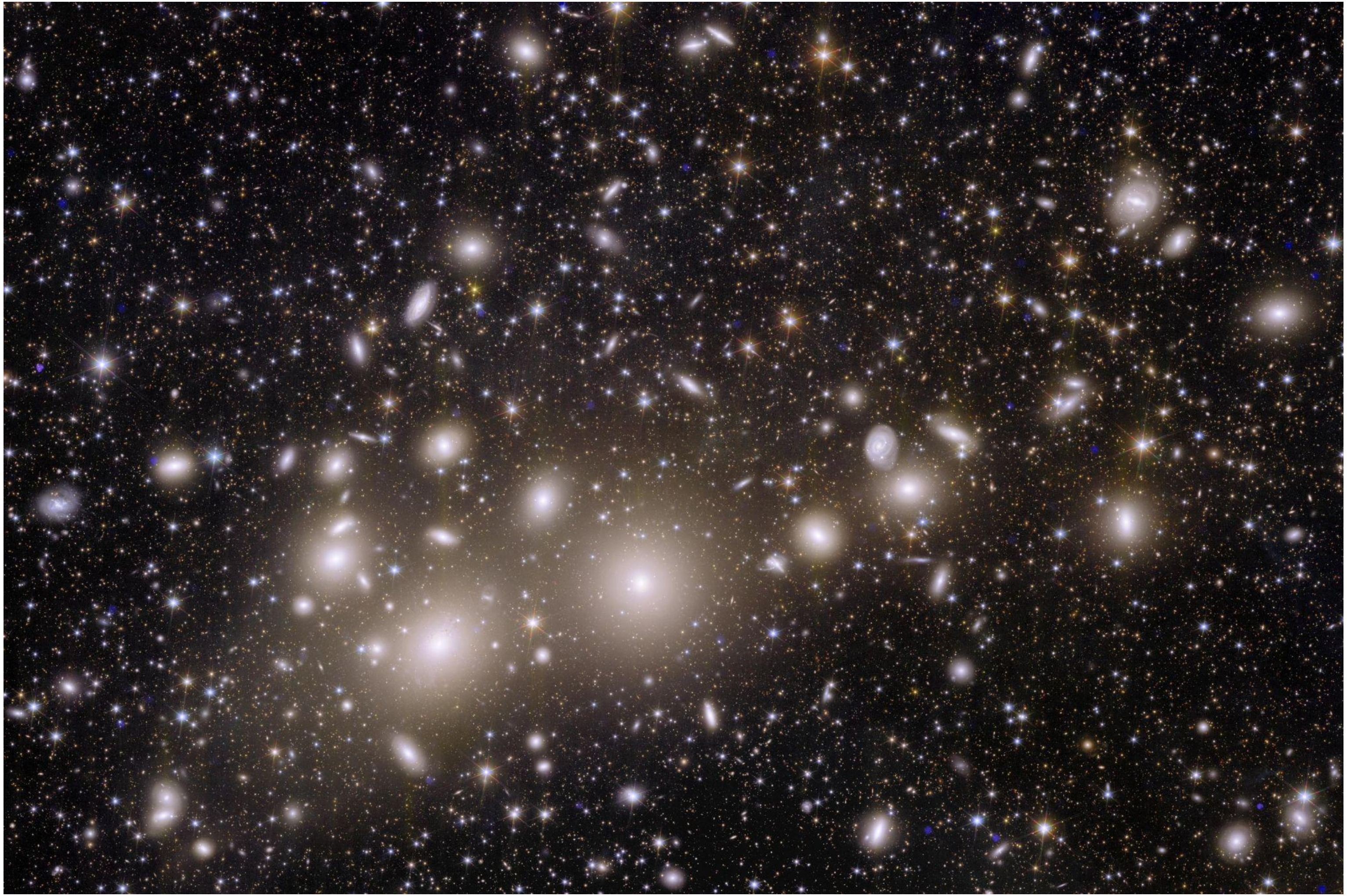


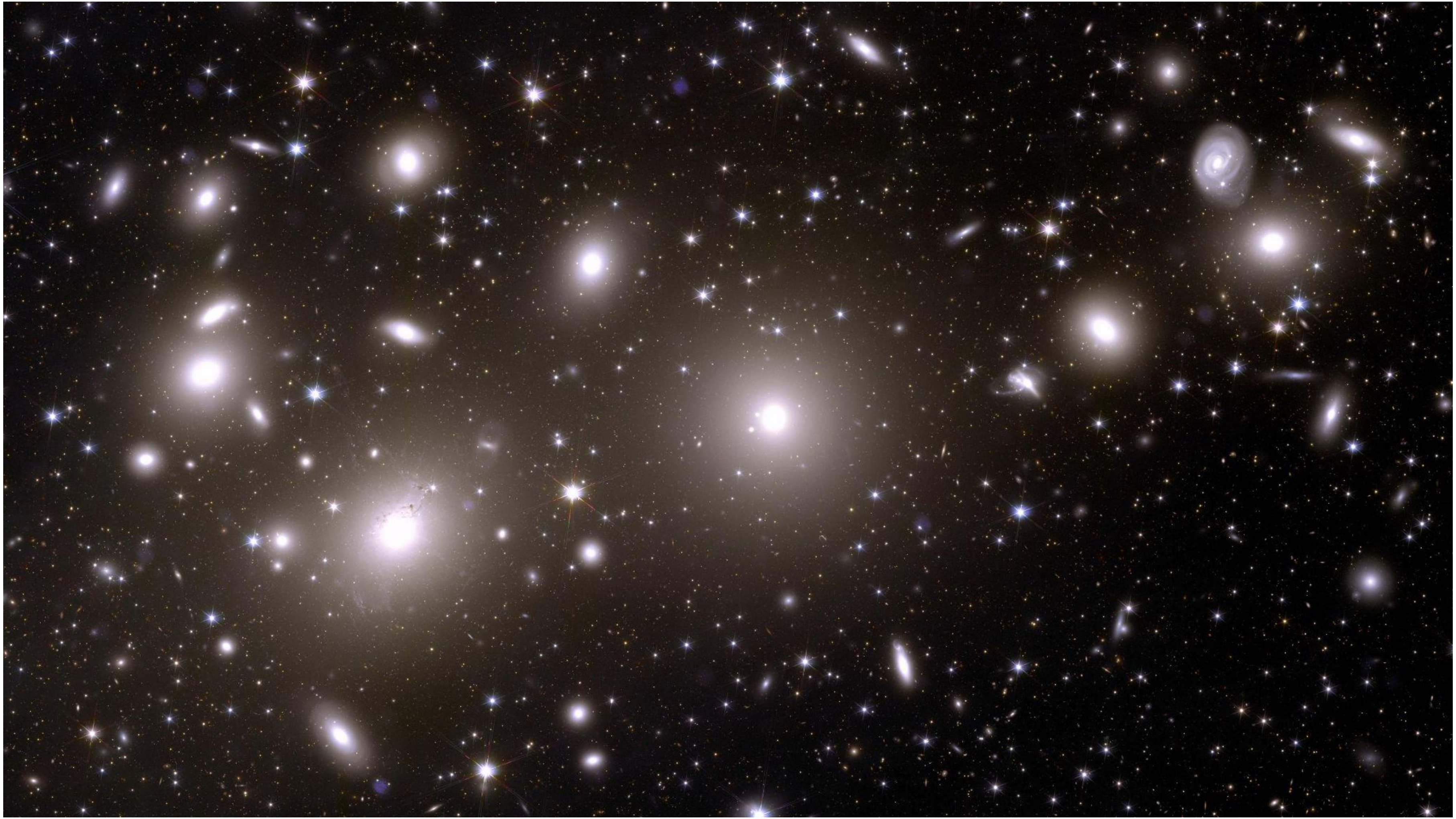


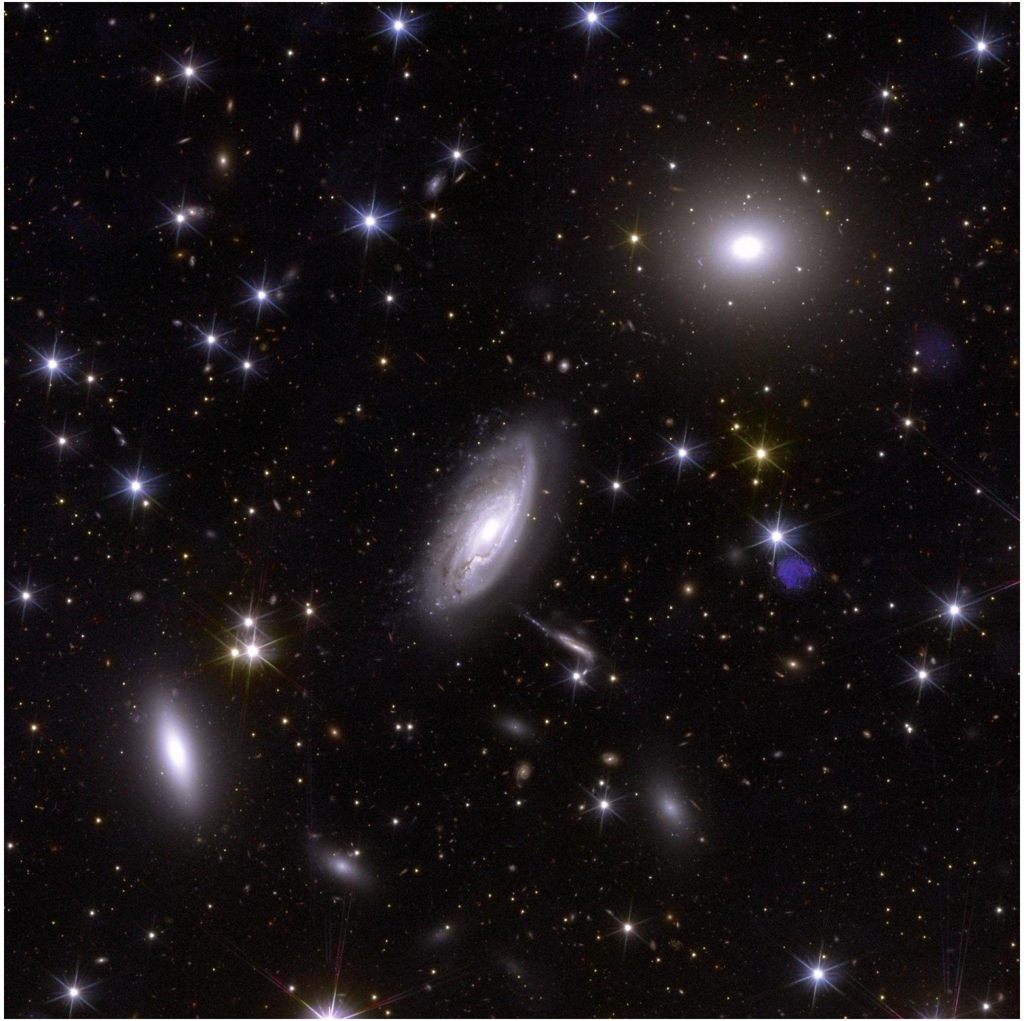


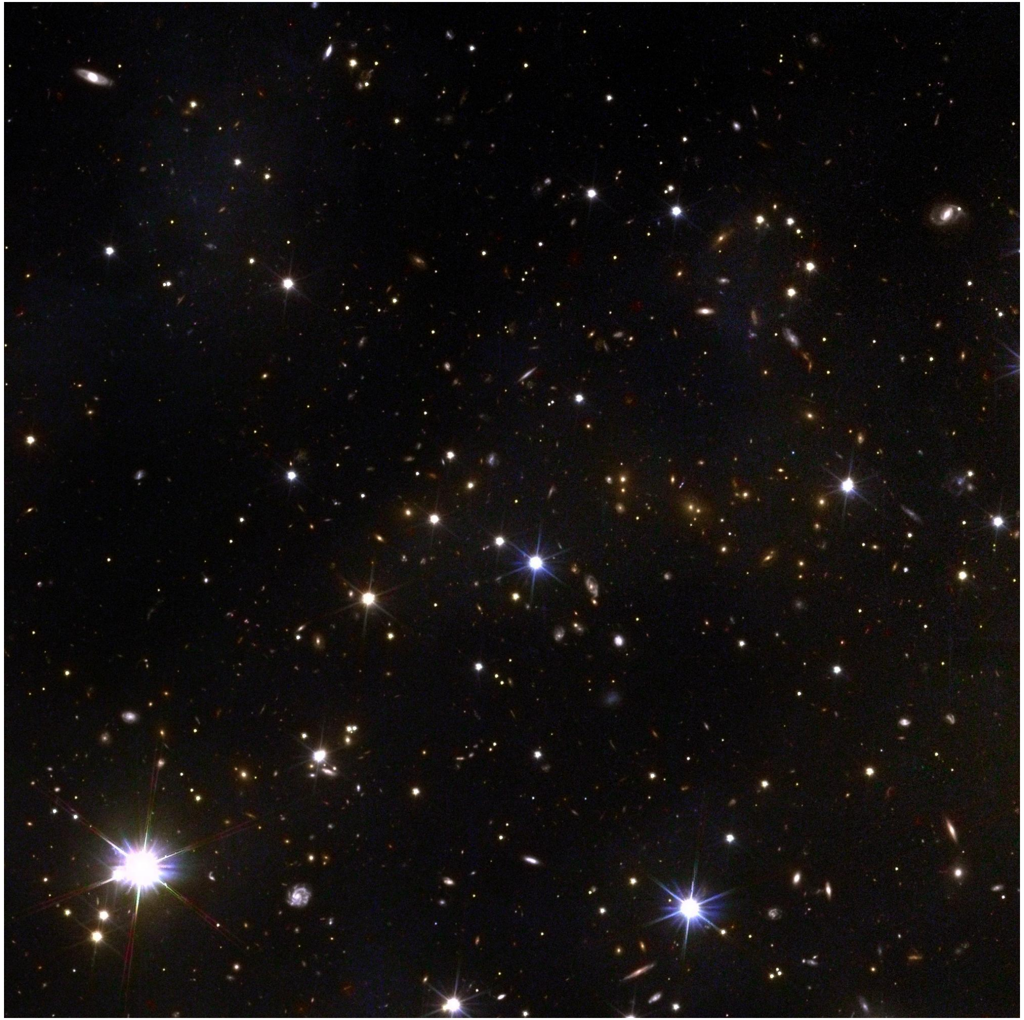










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