Transient search with EUCLID and the EMMETT project

(Euclid for Multi-MEssenger and Time-domain asTrophysics)

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The EMMETT project

Leveraging the ESA **Euclid mission's** unparalleled high spatial resolution and sensitivity in optical and NIR bands to address open questions in multi-messenger astrophysics.

Key targets

- **Bright Sirens:** Kilonovae resulting from binary neutron star mergers.
- **Dark Sirens:** Binary black hole systems detected via gravitational waves in previous/future runs
- **Dual AGN Systems:** Supermassive black hole pairs within a common host galaxy, serving as precursors to BBH mergers

The EMMETT project

Primary Objectives:

- **Measure BNS Rates:** Identify kilonovae in Euclid Deep Fields to provide accurate measurements of BNS merger rates within ~700 Mpc.

- **Refine the Hubble Constant :** Use "dark sirens" and Euclid's deep galaxy catalogs to provide independent estimates of the Universe's expansion history and address the Hubble tension (?).

- **Advance BBH Knowledge:** Characterize dual AGN systems to enhance understanding of black hole populations and predict future GW detection rates for LISA.

Methodologies

- **Multi-Survey Integration:** Combining Euclid data with wide-field resources like the Vera Rubin Observatory, the Very Large Survey Telescope and more

- **Time-Domain Analysis:** Conducting high-cadence monitoring of specific regions like the Euclid Deep Fields (North, South, and Fornax) to detect and classify transient events

- **Machine Learning :** Applying state-of-the-art AI/ML techniques to efficiently extract and identify transient candidates from massive Euclid datasets.

Euclid overview

1.2-m-aperture telescope covering a FoV of 0.53 deg^2 with a visual imager (**VIS**) and a NIR Spectrometer and Photometer (**NISP**)
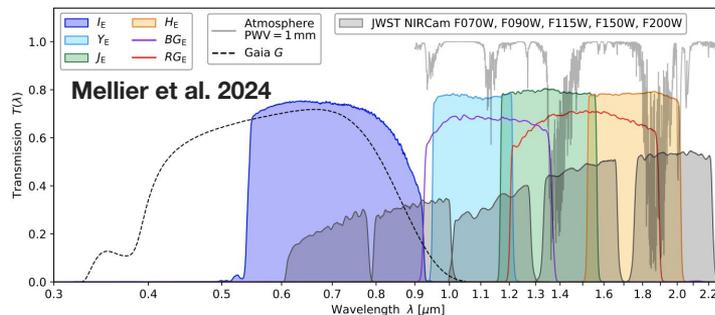
VIS

- Field of view   0.787x0.709 deg^2
- Wavelength range   550-900 nm
- Detector   36 arrays
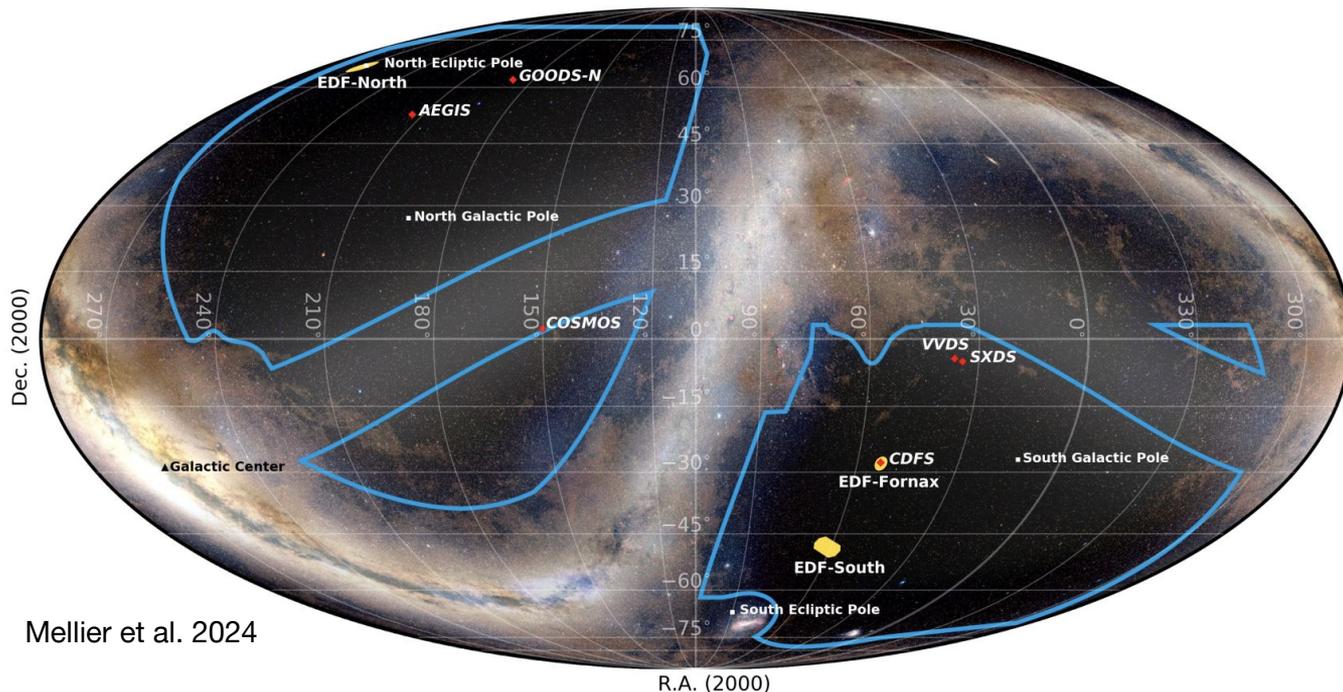   4kx4k CCD
- Pixel size   0.1"
- FWHM   0.2"

NISP

- Field of view   0.763x0.722 deg^2
- Wavelength range
  - imaging   Y J H
  - spectroscopy   1100-2000 nm
- Detector   16 arrays
     2kx2k HgCdTe detectors
- Pixel size   0.3"
- FWHM   0.3"
- Spec. Resolution   250
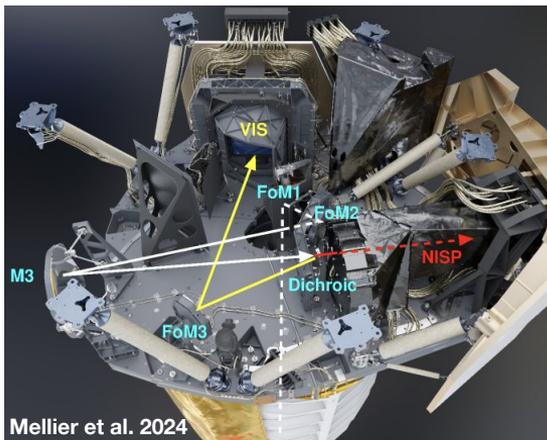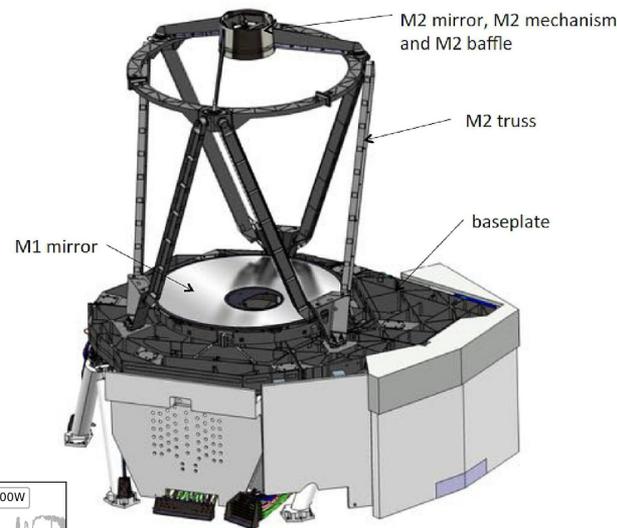
Mellier et al. 2024

Mellier et al. 2024

Euclid surveys

Wide Survey: 14,000 deg^2
VIS: 24.5 mag (10σ)
Y/J/H: 24.0 mag (5σ)

Deep Survey: 53 deg^2
VIS: 26.5 mag (10σ)
Y/J/H: 26.0 mag (5σ)

Auxiliary fields
NIR self-calibration field
Photo-z calibration field

Mellier et al. 2024
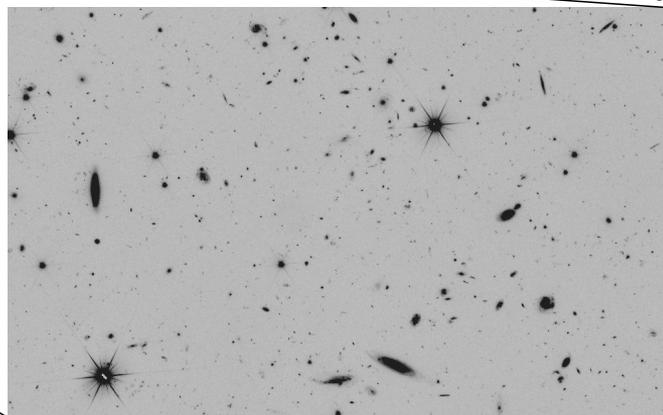
The SelfCal field

~3 deg² with monthly cadence during the entire nominal mission

- Optimisation of Difference Image Analysis tools for Euclid

- Development of a database of transients, tools for classification and cross-match

10 arcmin

Euclid preliminary
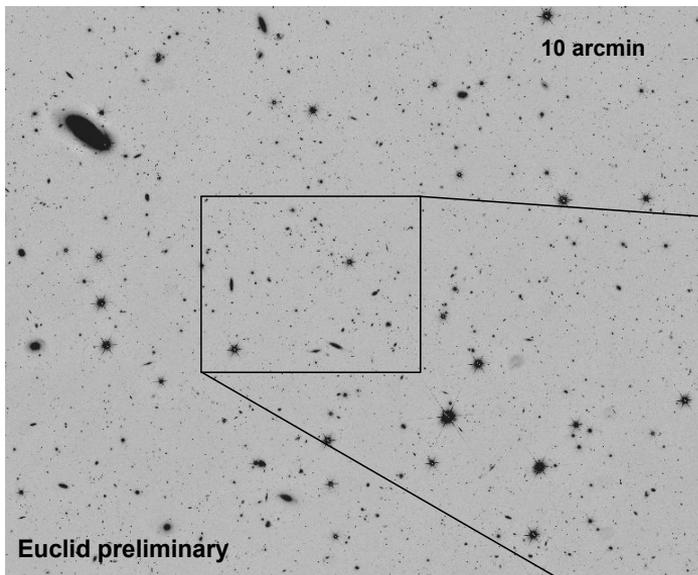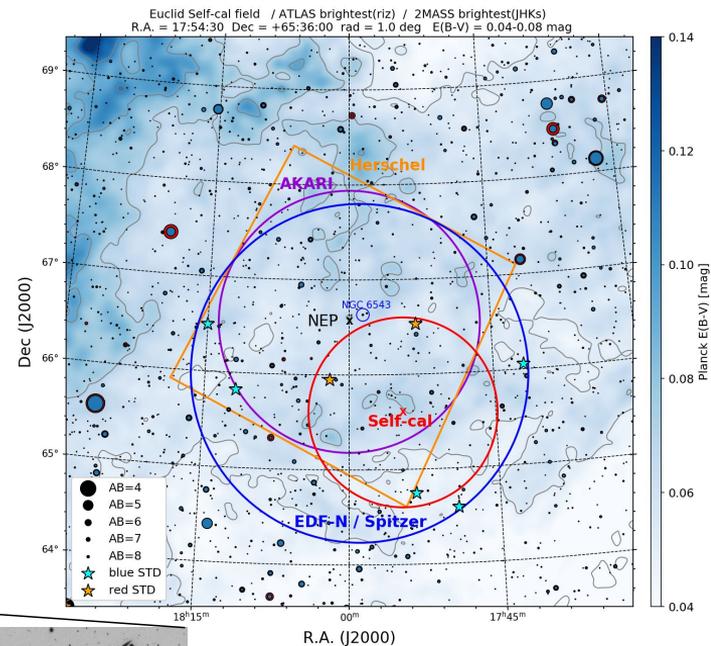
single epoch image analysis

stack of dithered exposures

Requirements

- Early access to raw-data
- Fast data reduction and analysis
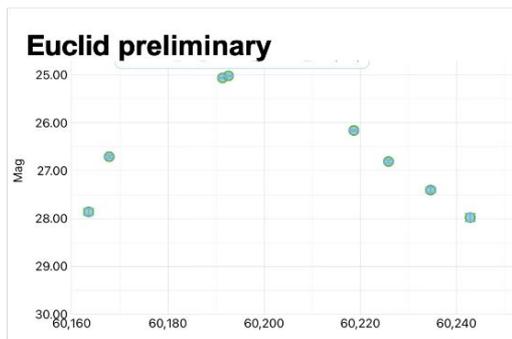
Difference Image analysis with Euclid
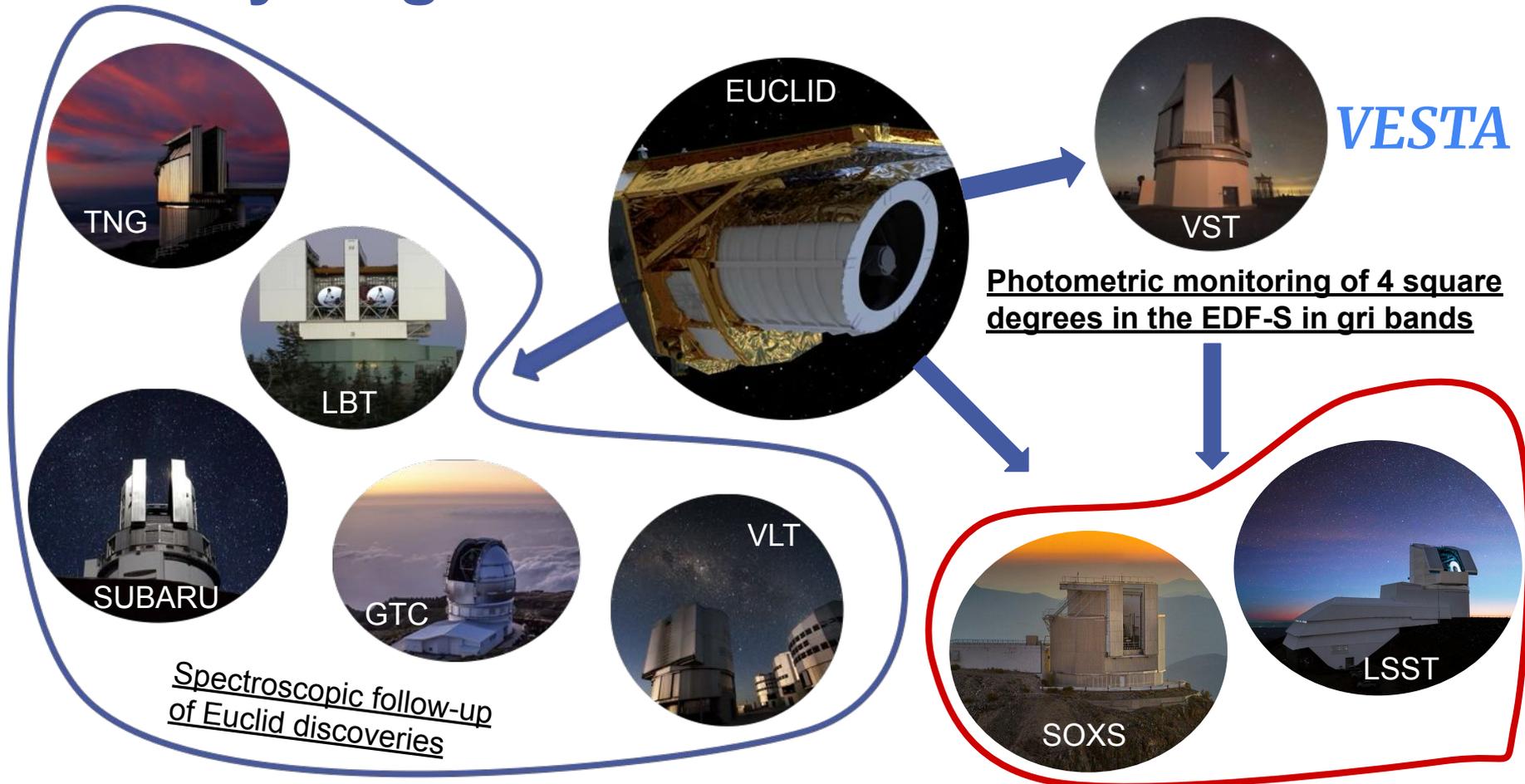
multi epoch images analysis   **optical** photometry
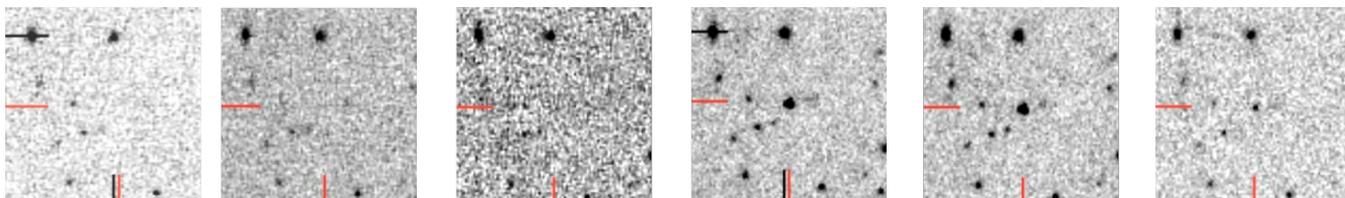
Difference images
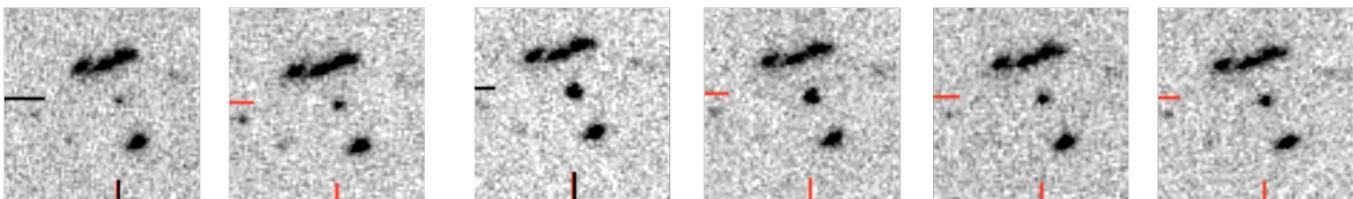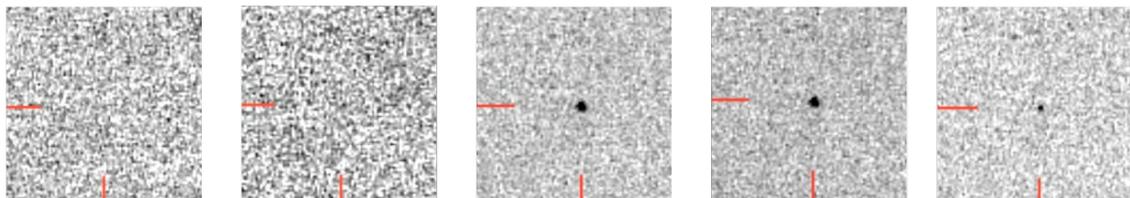
Difference images

Euclid Synergies

EUCLID

VESTA

VST

TNG

LBT

SUBARU

GTC

VLT

Photometric monitoring of 4 square degrees in the EDF-S in gri bands

SOXS

LSST

Spectroscopic follow-up of Euclid discoveries
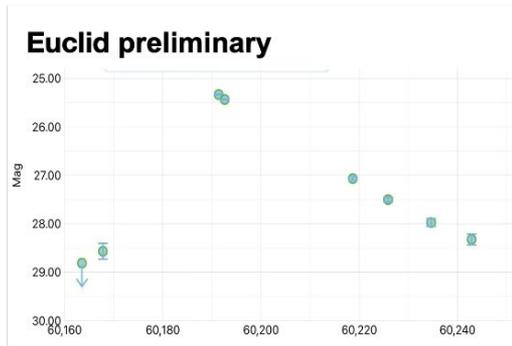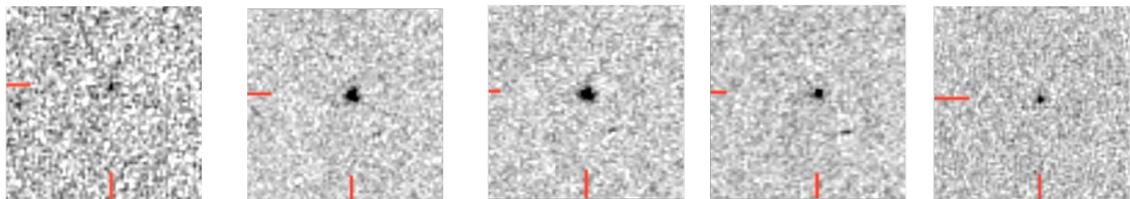
VESTA: VST-Euclid Synergies for Time-domain Astronomy

VST is the ideal facility to conduct a support survey for Euclid in preparation for LSST:

- Wide-field camera (1 square degree FoV)
- Excellent image quality and depth
- Same pixel scale of LSST (0.2 arcseconds)
- Very similar photometric system of LSST
- Location (Cerro Paranal) like the location of LSST (Cerro Pachón)
- Great past experience with transient surveys (e.g. SUDARE)
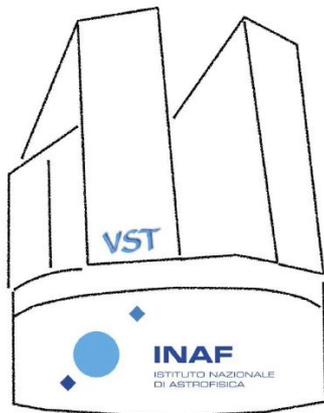
Survey start: late October 2024
Cadence: weekly (couples with gr or ri bands)
Area: 4 square degrees

**To be continued as
LSST in-kind contribution!**
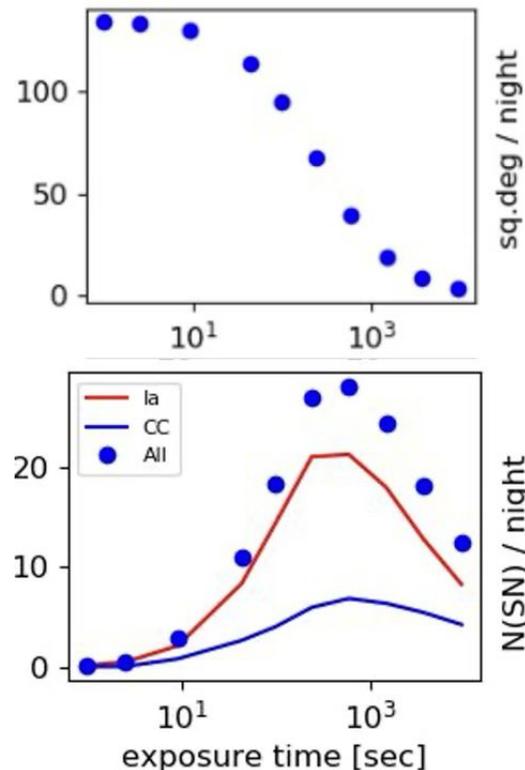
Early EDF-S visits for Euclid DR1

**10 Euclid DR1 visits from the CPS-South program:**

- 13-15 Aug. 2024
- 24-27 Aug. 2024
- 05-08 Sep. 2024
- 12-15 Sep. 2024
- 26-28 Sep. 2024
- 11-14 Dec. 2024
- 22-25 Dec. 2024
- 31 Dec - 03 Jan. 2025
- 11-13 Jan. 2025
- 21-24 Jan. 2025

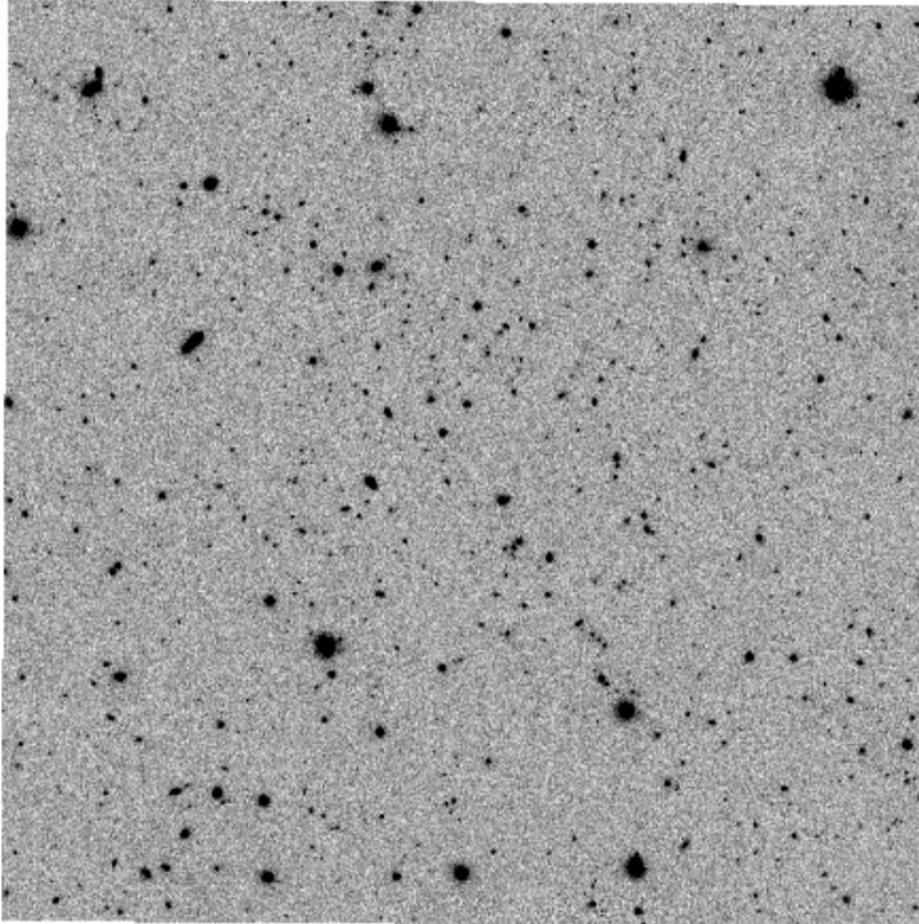**Rubin visits (DP2) from late 2025 released in summer… and alerts soon!**

EDF-S program starting with 4 nights from August 16th to September 2nd , 2025

Observed again with a similar pattern in January 2026, August 2026, …

Pilot project for the LSST in-kind contribution
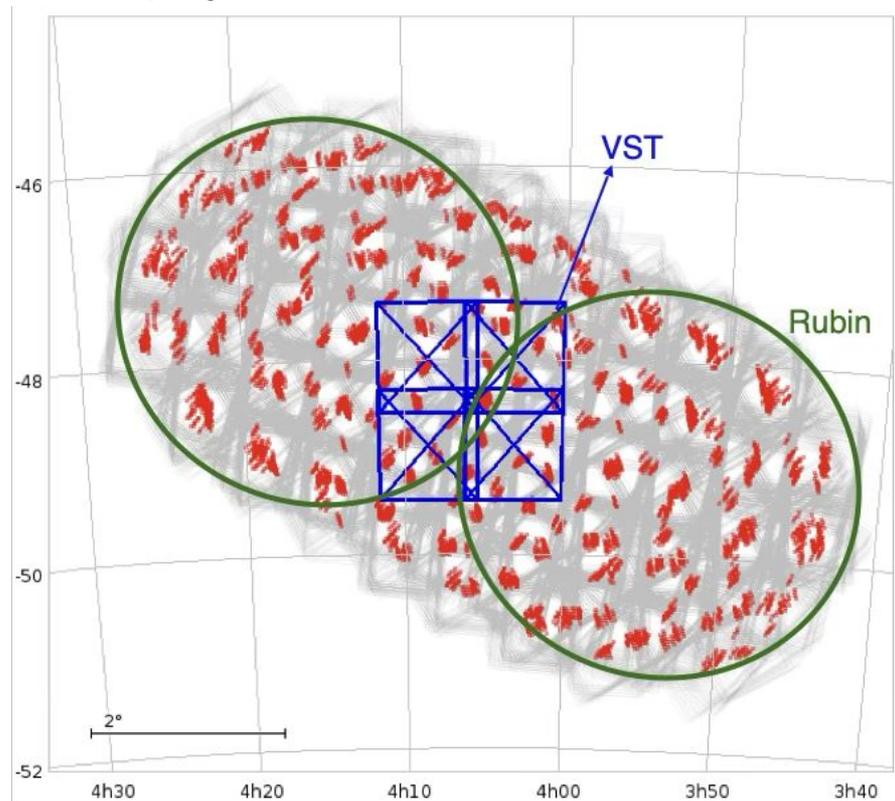
Difference Imaging on VESTA

Reduction of VST images with our own pipeline

Difference Imaging on VESTA
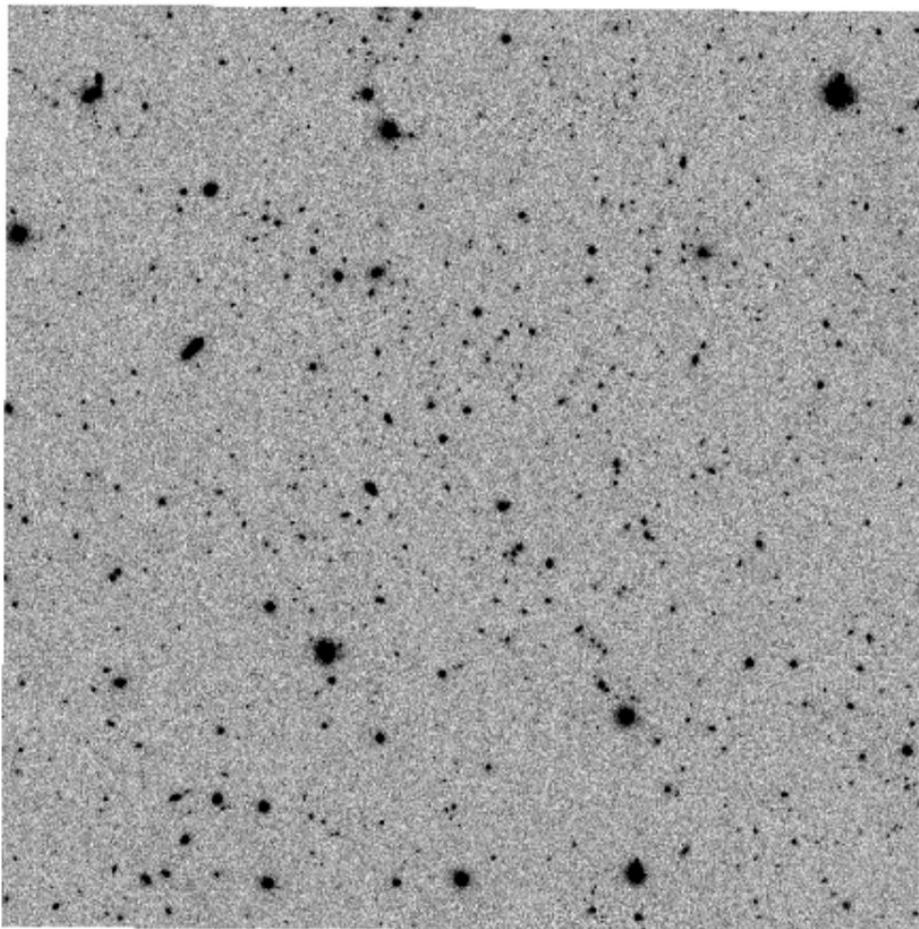
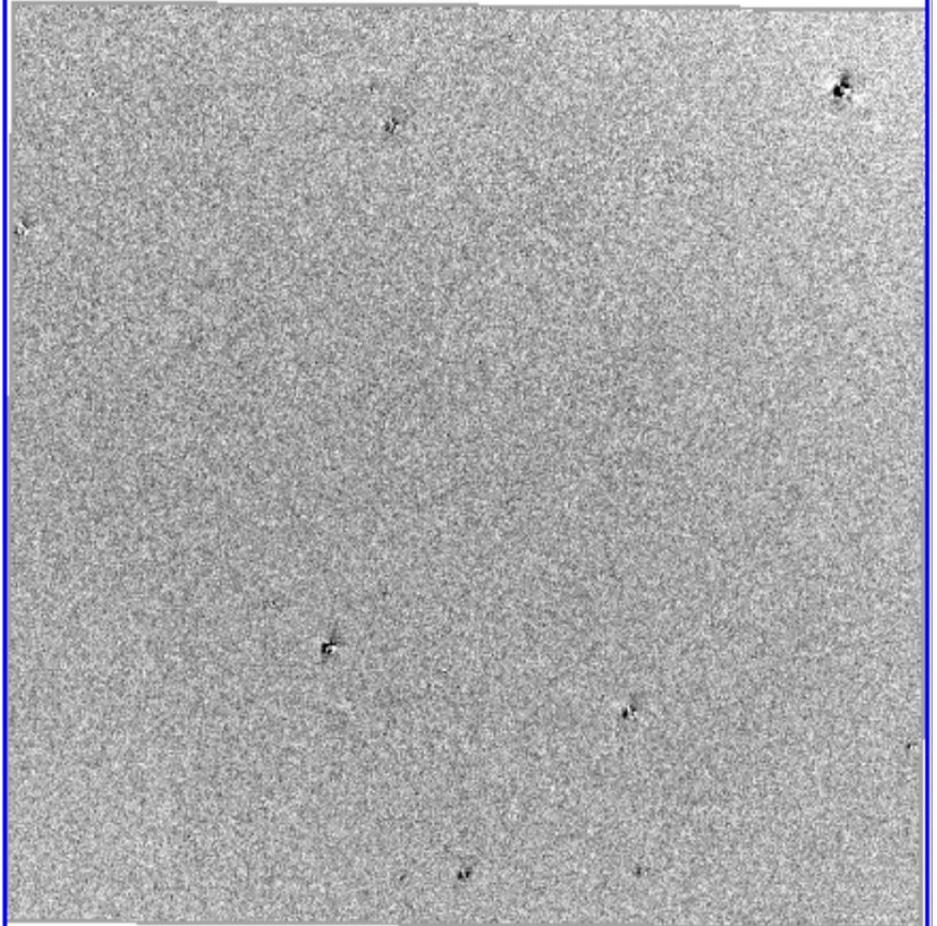
Reduction of VST images with our own pipeline

Search and PhotometRic Investigation of Transients at any Z

Difference Imaging on VESTA

Supernova candidates from VESTA

Supernova candidates from VESTA

Supernova candidates from VESTA

- Hundreds of possible SN candidates!

- Using only r-band visits over the first 6 months of pilot survey, with i- and g- bands to be added

- Observations resumed on August 2025 and are still running!

- Get ready for a real-time search

- Preparing a VESTA database, as SelfCal

- Forced-photometry on Euclid data (and vice versa)

- **Extension with future LSST data + other surveys!**

Take home messages

- Euclid has great capabilities in detecting transients…

    - Up to high-redshifts
    - Embedded in dust
    - Potential GW counterparts

- VESTA is a good pilot project for synergies between ground and space

    - Many interesting candidates
    - High-cadence observations
    - Tools for data-reduction and analysis ready to be generalized
    - **VST is a powerful survey supporting machine for LSST+Euclid!**

- We aim to exploit all available facilities to get a large sample of well sampled light curves, with spectroscopic follow-up and host information

Thank you!