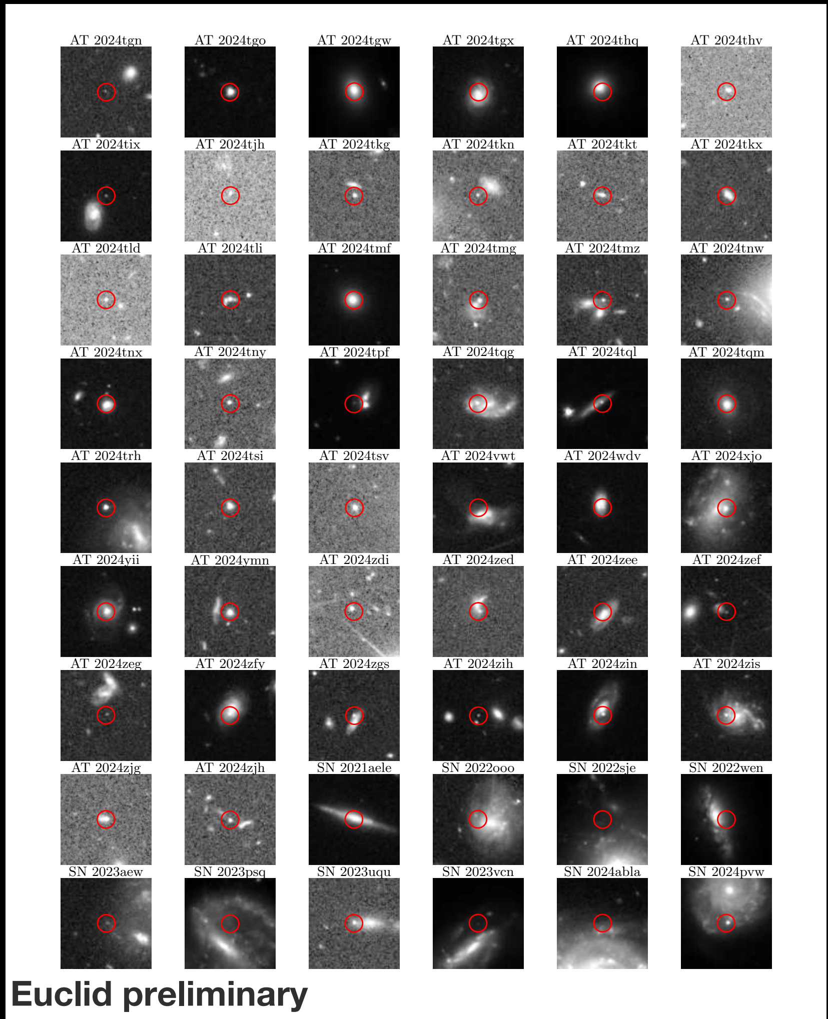


A selection of known transients imaged by Euclid
(Duffy et al., 2025)

First results from Euclid

Isobel Hook, Lancaster University
Euclid SN & Transients SWG

Euclid consortium

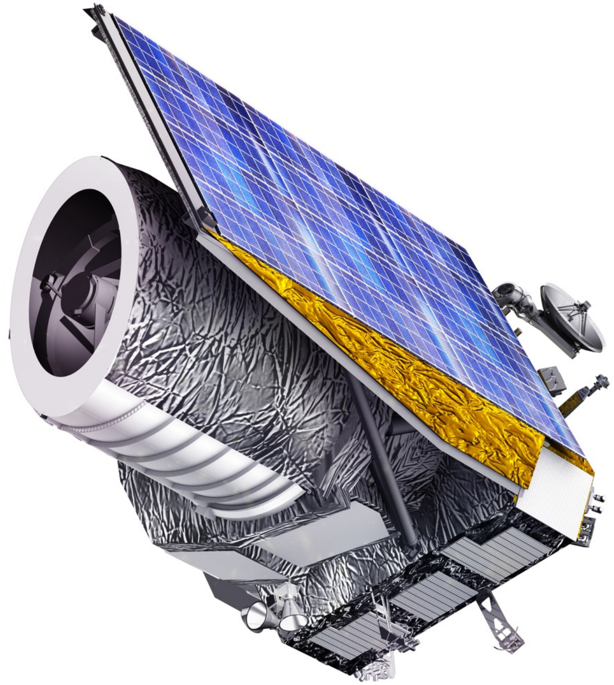
Euclid

- ESA mission with NASA participation, launched in July 2023

- 1.2m space telescope

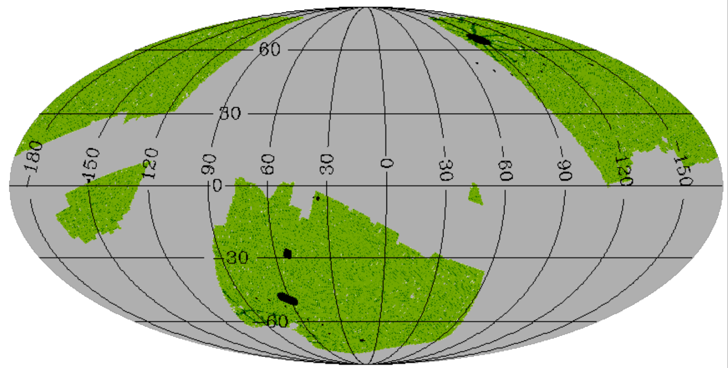
- Wide field instruments (0.5 sq deg)
  - VIS: 530-920nm imager, 0.1” pixels
  - NISP: Y, J & H band imager, 0.3” pixels

    920-1850nm spectrometer



- Wide Field Survey: 14 000 deg^2 single epoch over 6 yr
  - VIS: 26.7 mag (5σ point source)
  - Y/J/H: 24.4 mag (5σ point source)

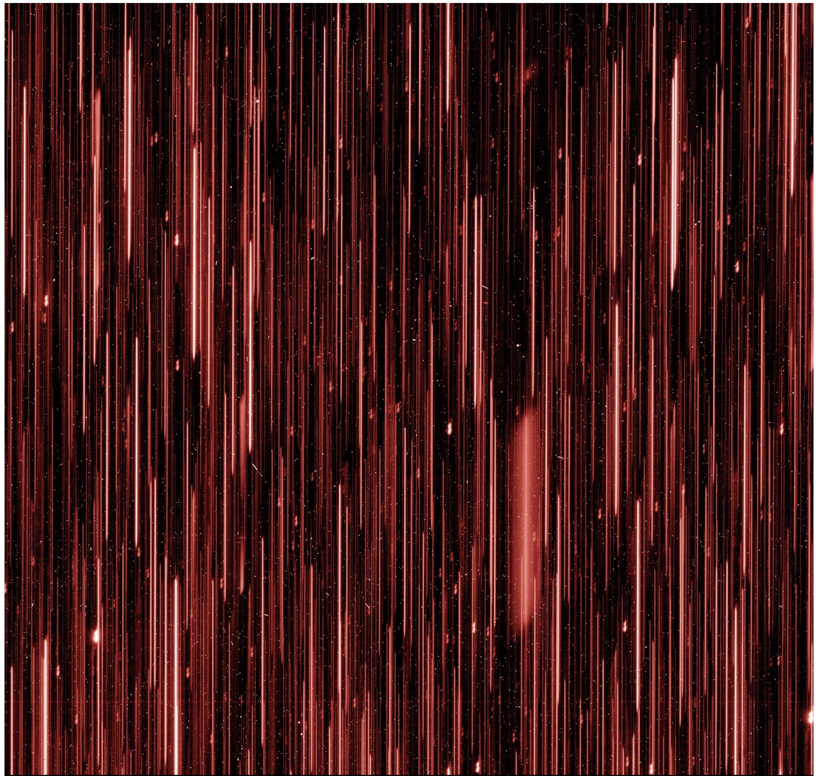
- Deep Field Survey: 53 deg^2 with ~6 epochs per year



Above: Euclid sky coverage

Isobel Hook, An Extraordinary Journey, Padova, April 2025

Euclid's high-resolution imaging and spectra



Early commissioning test image, NISP instrument (grism mode)

Euclid Early Release Observations of the Perseus cluster field
ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi

Transient science with Euclid

- Euclid survey strategy is not ideal for transients. BUT wide-field, high resolution is unique
- NIR is particularly valuable: high-z and/or dust-obscured transients

Deep fields: multiple epochs

Searching for new transients:

Ia, CC, and long-duration / high-z SNe e.g, pair instability SNe and SLSNe

Wide Survey: single epoch

Detection of known transients - including pre-discoveries!

Hosts of known transients

- Applications to SN cosmology, rates, transient physics, unusual transients, lensed SNe…
- Note: a dedicated Euclid transients survey would be ideal (Astier et al. 2014)

Supernova and Transients SWG

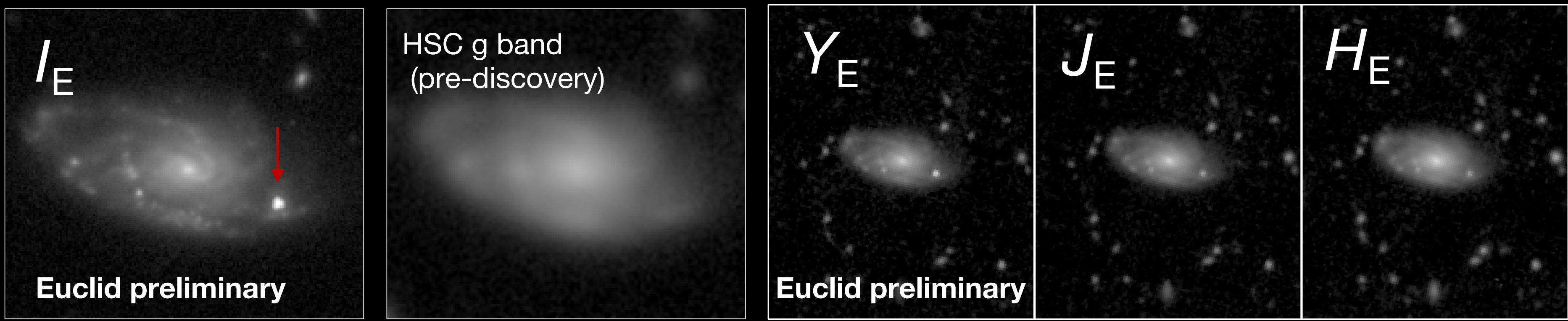
- SWG Members:

Jose M. Diego, Enrico Cappellaro, Isobel Hook, Eric Linder, Savvas Nesseris, Maria Teresa Botticella, Kerry Paterson, Charling Tao, Nao Suzuki, Takashi Moriya, Peter Jonker, Filippo Mannucci, Yannick Copin, Frédérick Poidevin, Maria Vincenzi, Luca Izzo, Lluís Galbany, Ashley Chrimes, Caitlin Casey, Eliana Palazzi, Vincenzo Petrecca, Chris Duffy, Rubina Kotak, Luciano Nicastro, Christa Gall, Seppo Mattila, Agnes van Hoof, Jens Hjorth, Ranga-Ram Chary, Dominique Fouchez, Joyce van Dalen, Jonathan Quirola Vasquez, Peter Nugent, Yushan Xie, Stefano Cavuoti, Nicholas Walton, Javier Sánchez Sierras, Masaomi Tanaka, Nadejda Blagorodnova, Ana Afonso, Irene Salmaso, Alejandra Melo, Ariel Goobar

- Extra thanks for supporting special access to data and ESA Datalabs

Rene Laureijs, Valeria Pettorino, Bruno Altieri, Sandor Kruk

A serendipitous discovery



- Discovered in early images by Javier Graciá-Carpio, a member of the Euclid SGS team
- Detected in Euclid VIS and NIR Y,J,H
- Also imaged with VST (M.T. Botticella and E. Cappellaro)
- Spectroscopically classified with GTC

A serendipitous discovery

Enrico Cappellaro found a SN in the same galaxy in 1999 !

Galaxy has $z = 0.14$

SN 1999gu was classified as type II

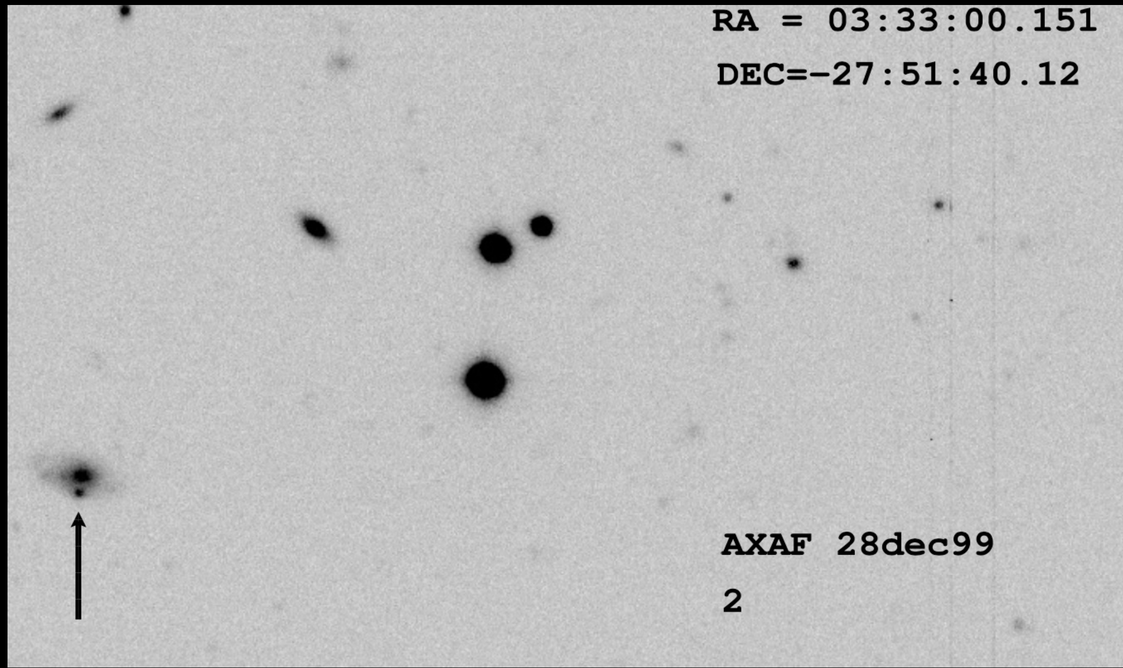


Image from WFI @MPG/ESO 2.2m
Credit: Enrico Cappellaro

Euclid Q1: Photometric Studies of Known Transients

Duffy et al., 2025

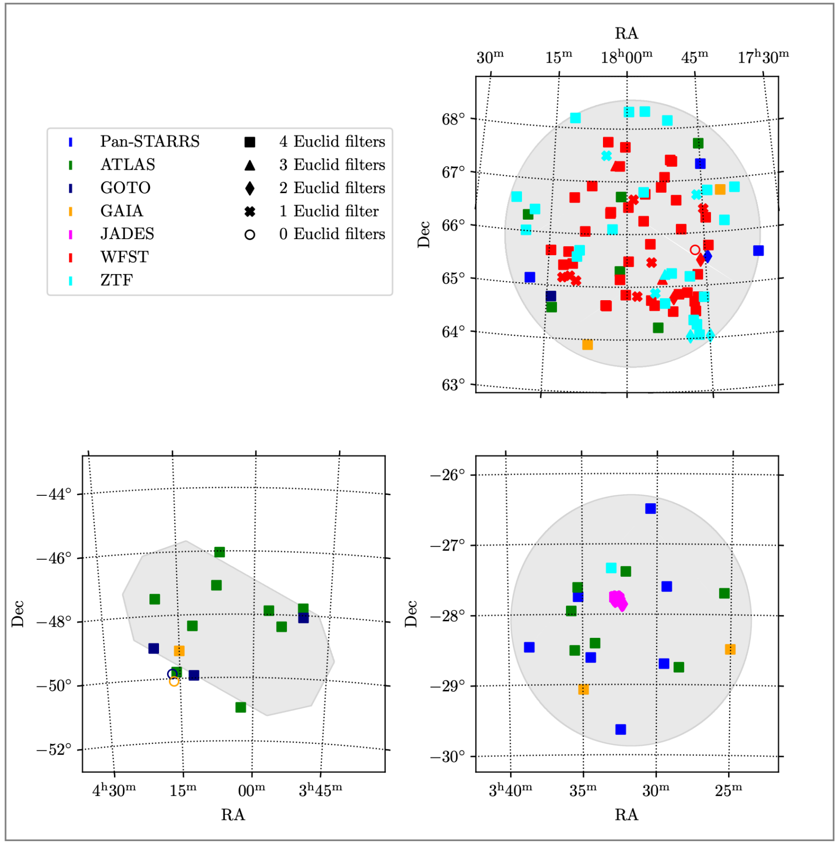
- Project contributors: C. Duffy, E. Cappellaro, M.T. Botticella, I. Hook, F. Poidevin, T.J. Moriya, A.A. Chrimes, V. Petrecca, K. Paterson, A. Goobar, L. Galbany, R. Kotak, C. Gall, C. M. Gutierrez, C. Tao, L. Izzo

- Euclid Q1 data: one epoch in each of the deep fields (63 sq. degrees total)
  - taken July-September 2024
- Project goals:
  - Demonstrate the capability of Euclid for transient science
  - Pave the way for future work - the wide field survey
  - Add scientific value to known transients from NIR, e.g. to help classifications

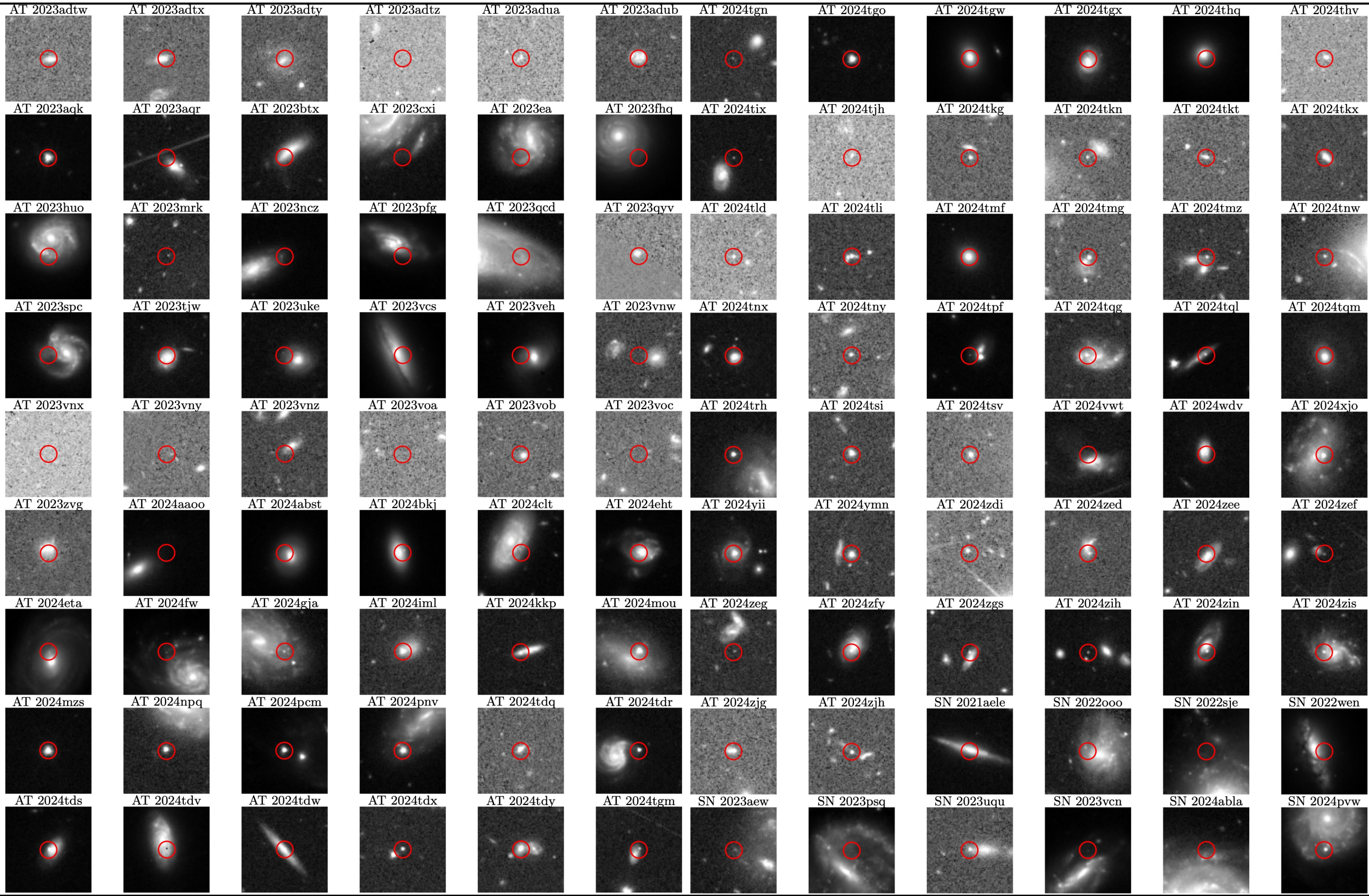
Euclid Q1: Photometric Studies of Known Transients

Duffy et al., 2025

- Matched known transients in the Q1 fields
  - any transient from 1 year prior to Q1 observations and up to 05/12/24
  - any transient from 3 years prior *AND* discovered brighter than 18th mag
- 164 transients from TNS met these criteria



Duffy et al. 2025

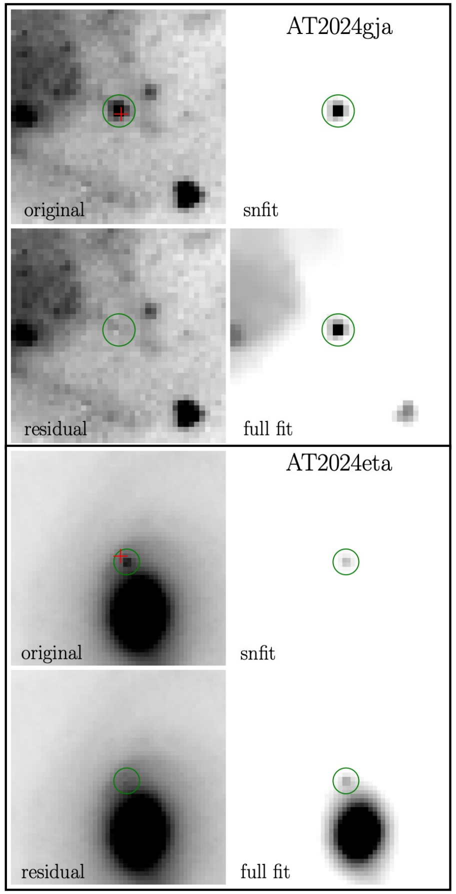


Adapted from
Duffy et al. 2025
Appendix B

Q1 Photometry

E. Cappellaro

- PSF photometry with a local background subtraction
- Consider a source detected if:
    - S/N $\gtrsim$ 3
    - Offset 0.1 – 0.3 from TNS position
    - Offset from the host galaxy centre
- Otherwise report an upper limit
- Note: without difference imaging we can’t be 100% certain of a detection
- Result: 70% of transients brighter than 24th mag within 6 months of Euclid observations were detected



Detection

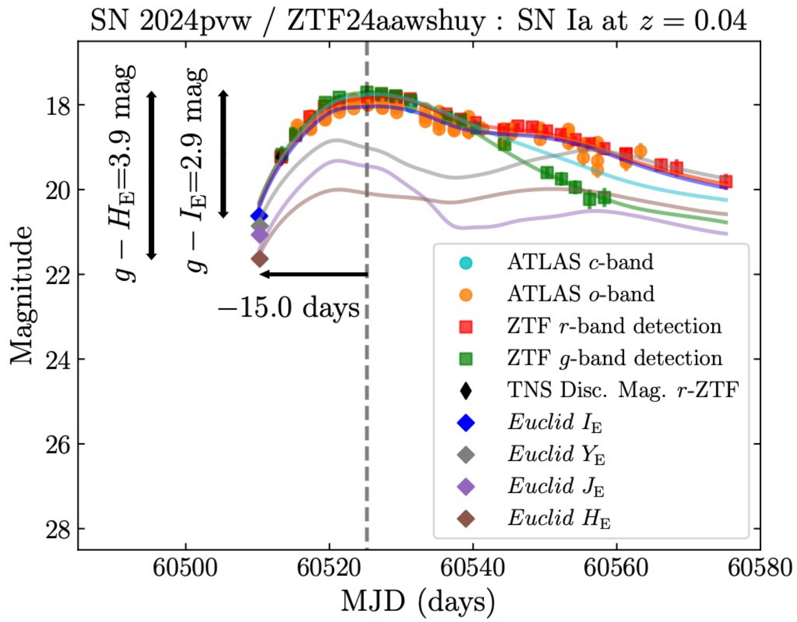
Inconclusive detection: upper limit recorded

(low S/N and relatively large offset from reported position)

Above: examples of PSF fitting adapted from Duffy et al. 2025 Fig. 3

Q1: Early-time observations

- SN 2024pvw: Type Ia
    - Euclid observed 3 days before reported discovery
    - Euclid detections in all 4 bands
    - Rare, early detection of a Hubble flow SN Ia
    - Useful to constrain progenitors
    - Especially with NIR as it may reveal pre-existing structures such as accretion disks

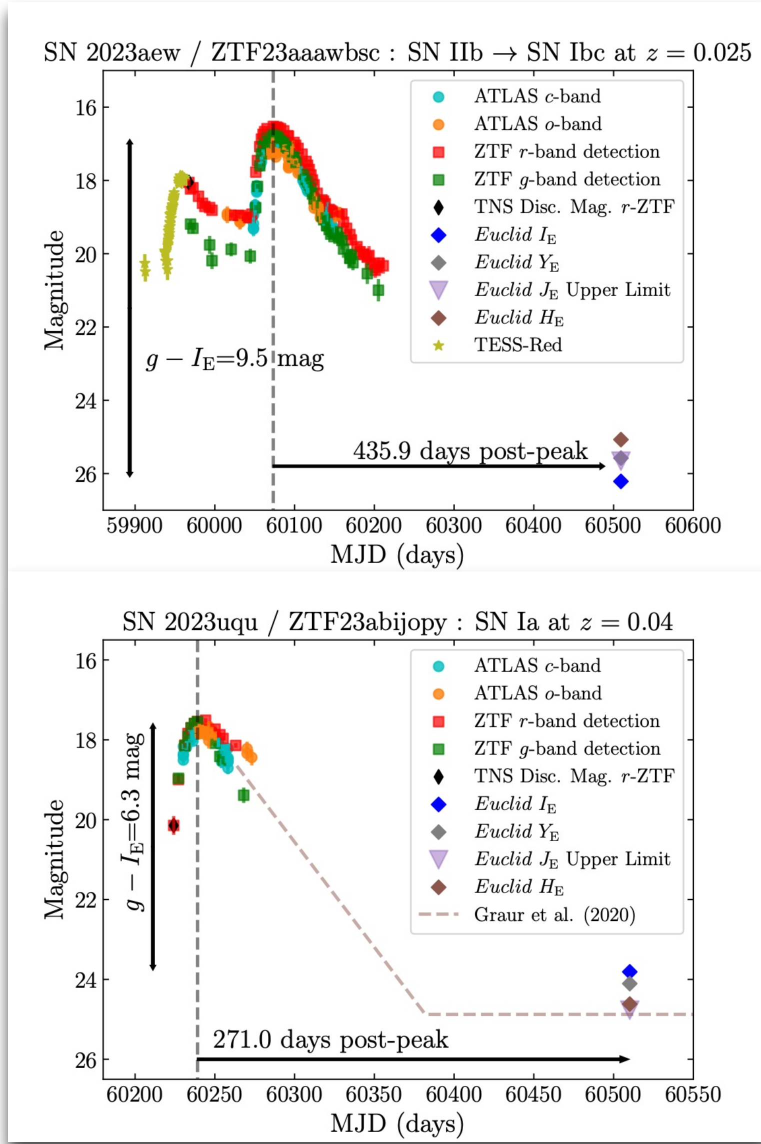


Duffy et al. 2025 Fig. 7

Q1: Late-time observations

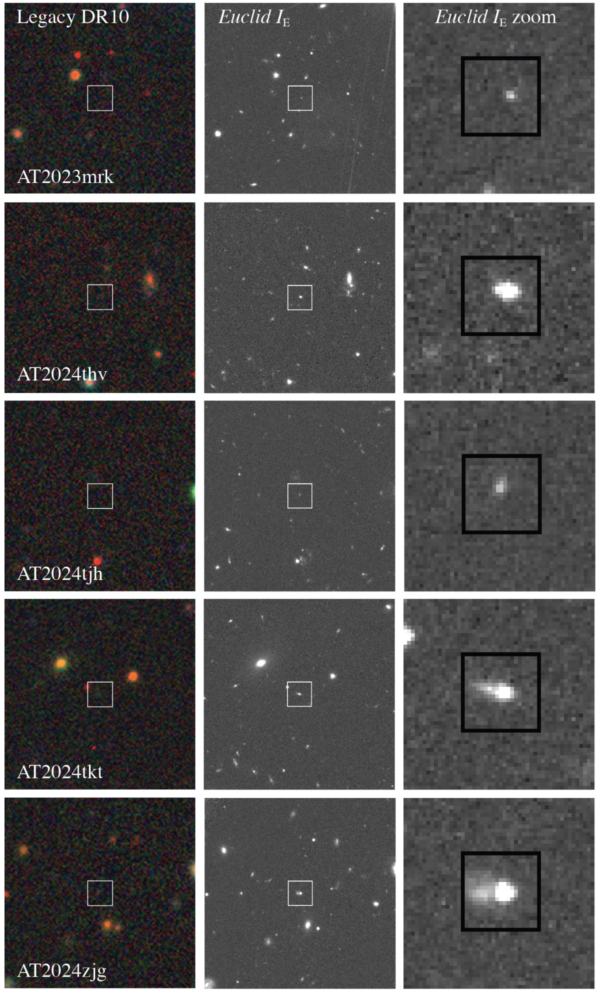
- SN 2023aew - Type Ibc
  - The cause of multiple peaks is unclear
  - Observations show decline consistent with nuclear decay
  - Other potential power sources but need later observations
- SN 2023uqu - Type Ia
  - NIR observations consistent with the expected plateau at 150-500 days
  - Late phase NIR light curves essential to understand radiative transfer in Type Ia ejecta

Duffy et al. 2025 Fig. 9



Q1: Adding host galaxies

- Euclid can detect hosts of transients previously classed as “hostless”
- Matched the 11 “hostless” targets from our sample with Euclid catalogues' galaxy/point-like probabilities
- 5 have high probability of host galaxy detection
- Remaining 6 were point-like; could be dwarf galaxy, variable star or QSO



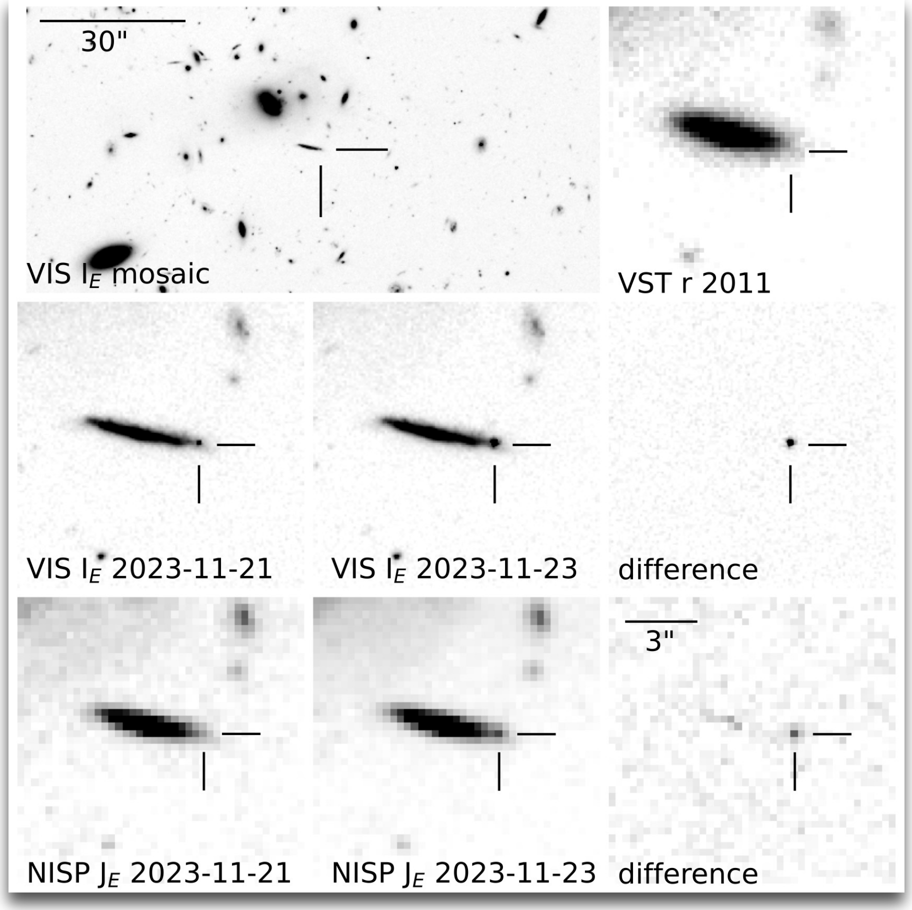
Probable host associations in Euclid comparing with Legacy Survey (Duffy et al. 2025)

Looking Beyond Q1

- Euclid DR1 (Oct 2026 release) will be about 30 times larger area than Q1
- Final Euclid survey area >200 times larger than Q1
- Will also have Rubin transient alerts

- Repeat observations of deep fields allow searching for new Euclid transients – difference imaging
- First example (right)
  - Transient near an SDSS galaxy with $z = 0.246$
  - Seen in VIS and NISP difference images
  - Colour consistent with a SN, but Type unknown

AT2023adqt, Fig. 49 Euclid I Overview of the Euclid mission, Euclid Collaboration: Mellier et al. 2024



A Key Project with DR1 data

- **Aims**
  - Demonstration of Euclid capabilities to detect transients
  - Classification of transients and measurement of SN rates
- **Starting point: SELF CAL FIELD**
  - ~3 deg^2 field with multi-epoch observations
  - 9 epochs during PV phase
  - 1 epoch per month during nominal mission
- **Requirements**
  - Timely access to raw data

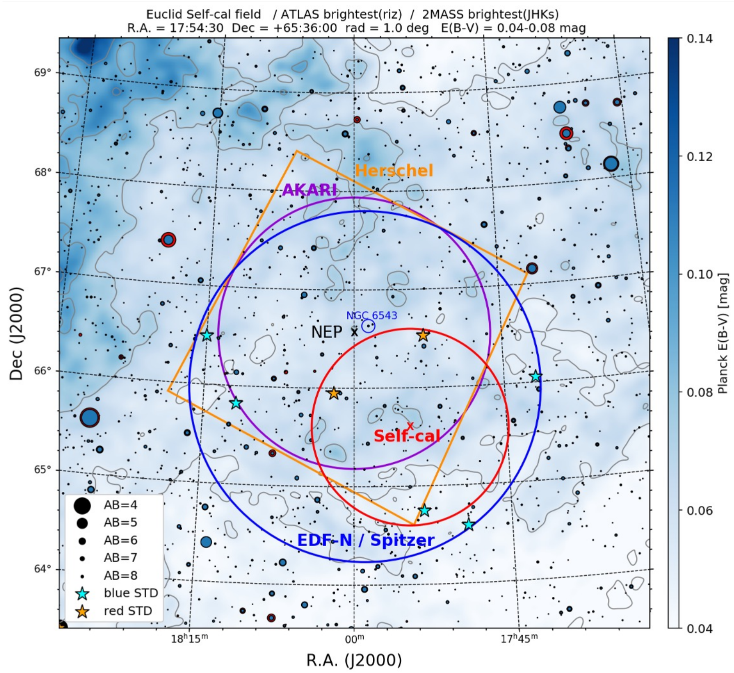
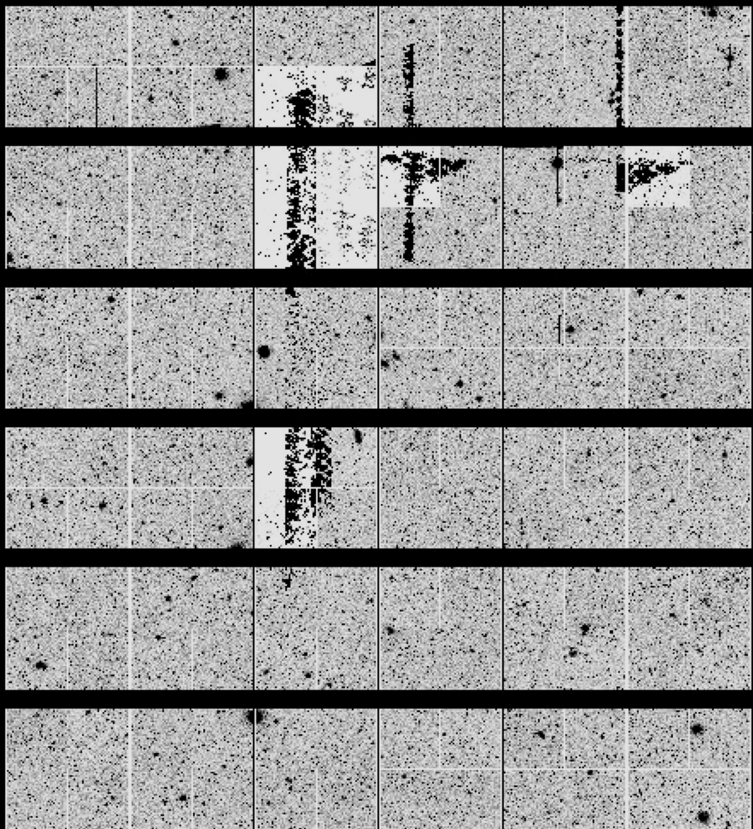


Image Credit:
Euclid Calibration framework

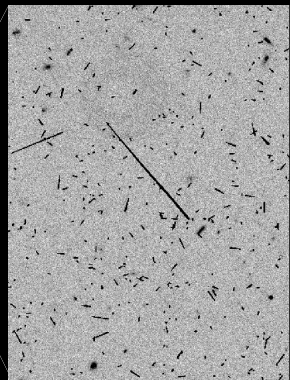
Difference Image Analysis on Euclid data

single epoch image analysis

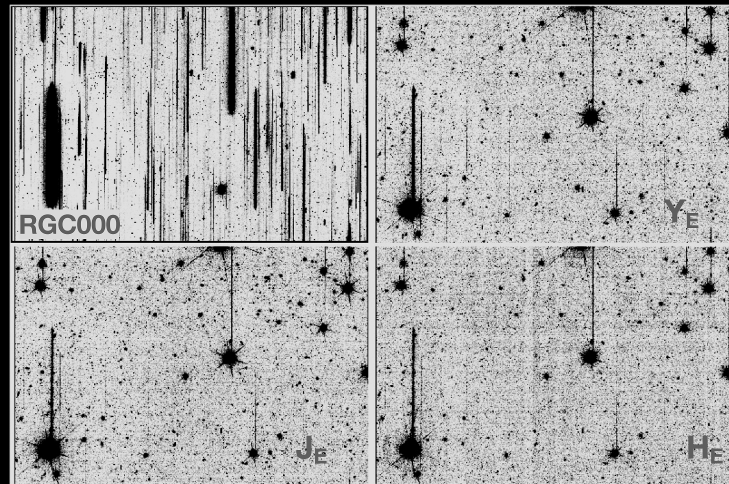
cosmic ray removal



10 arcmin



persistence correction for NISP data

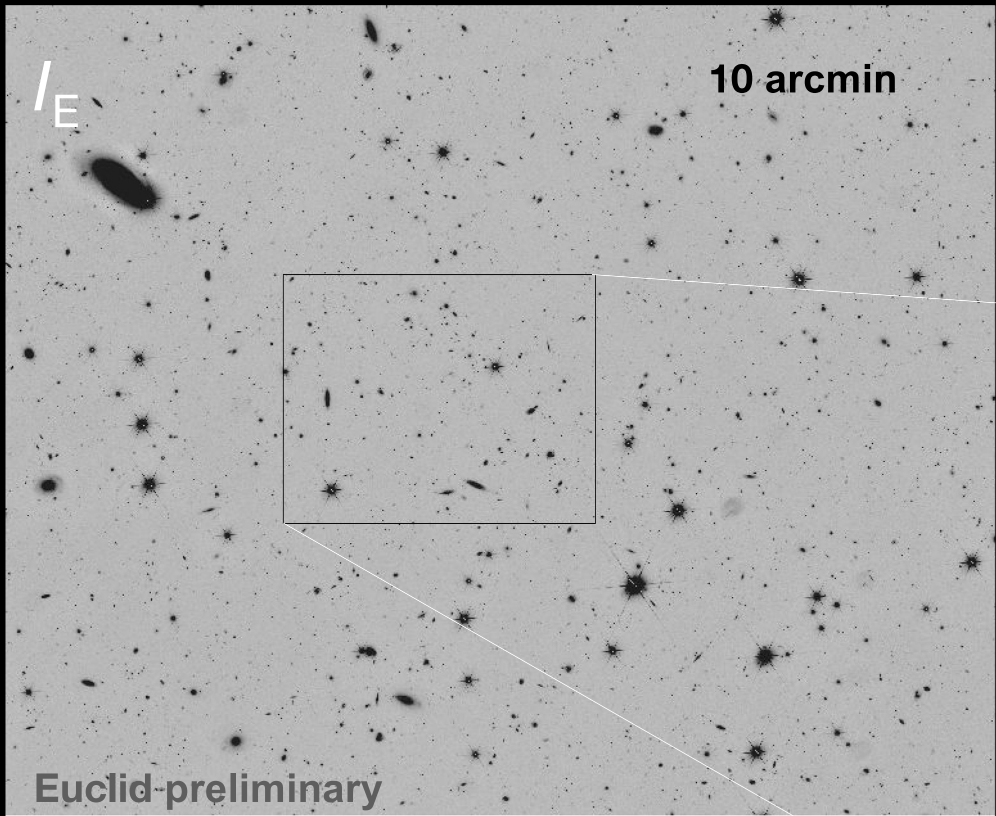


Euclid Transient pipeline led by Enrico Cappellaro

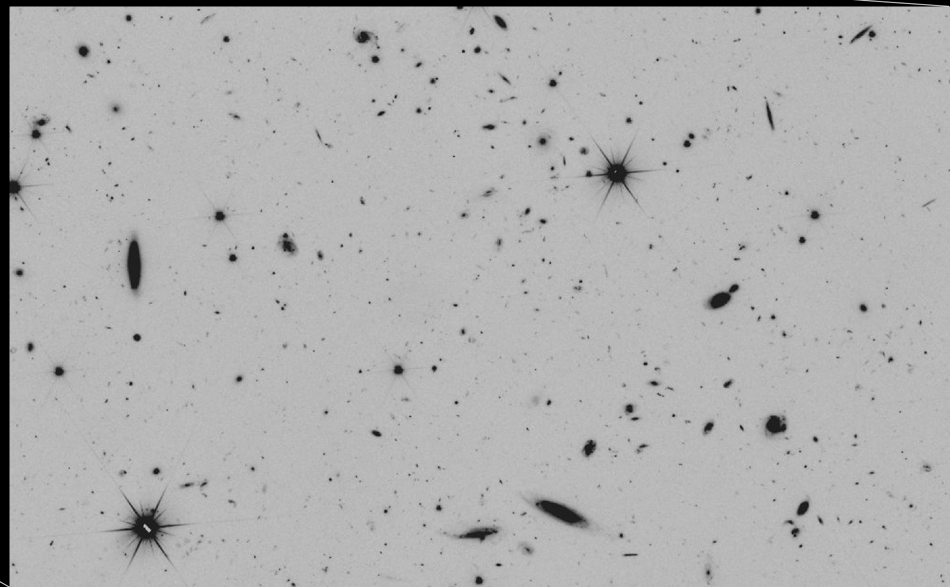
- astrometric calibration
- photometric calibration
- image subtraction and transient detection

Difference Image Analysis on Euclid data

single epoch image analysis – Euclid VIS (optical) images



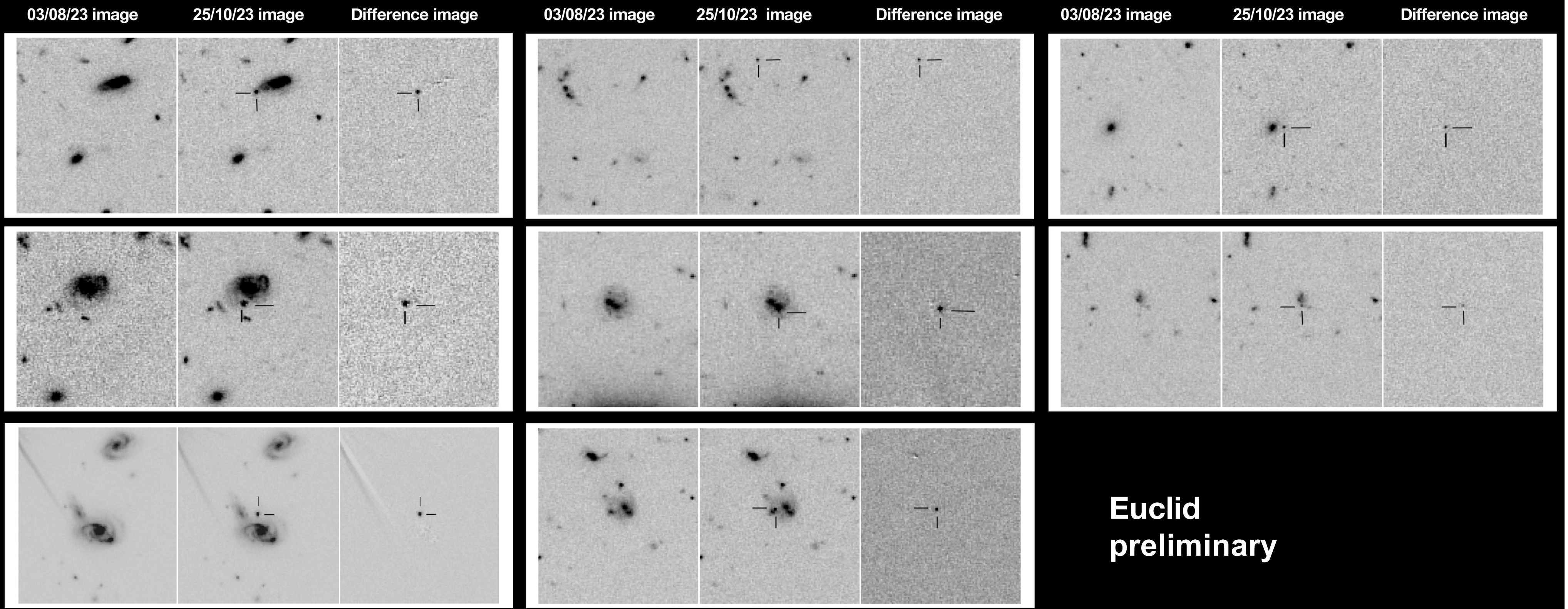
stack of dithered exposures



Difference Image Analysis on Euclid data

single epoch image analysis

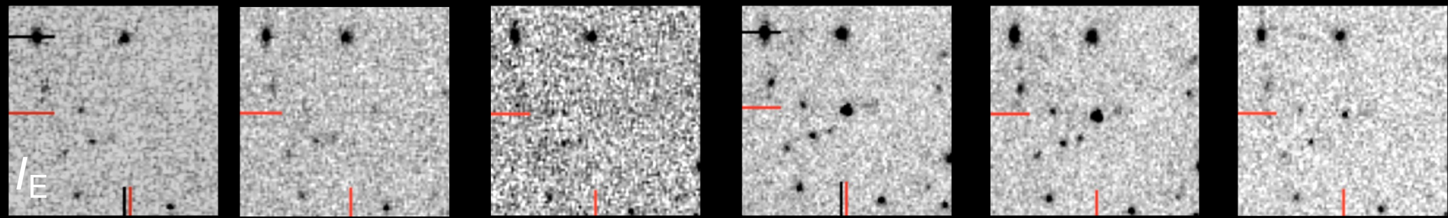
Difference with reference image and detection of transients on difference image



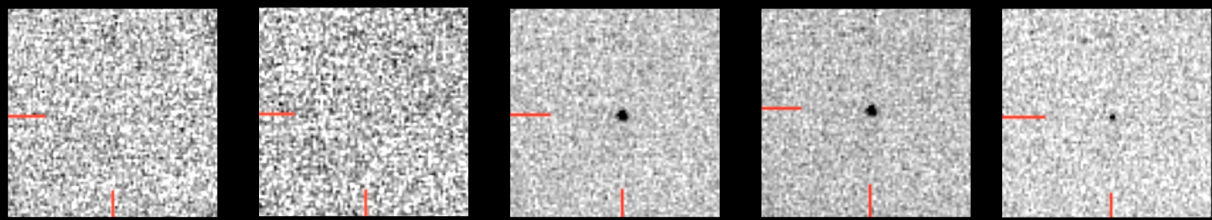
Euclid preliminary

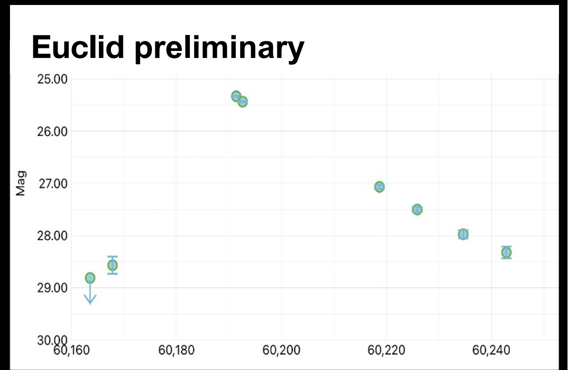
Difference Image Analysis on Euclid data

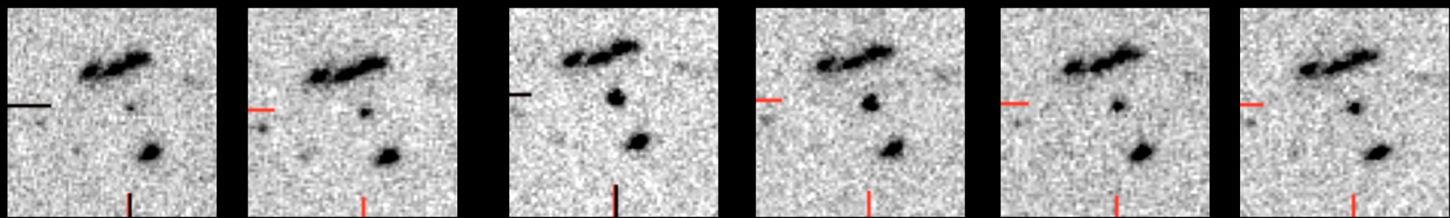
multi epoch image analysis (optical)



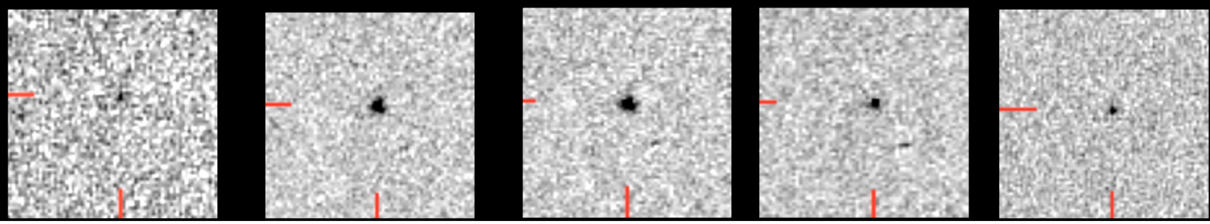
Difference images

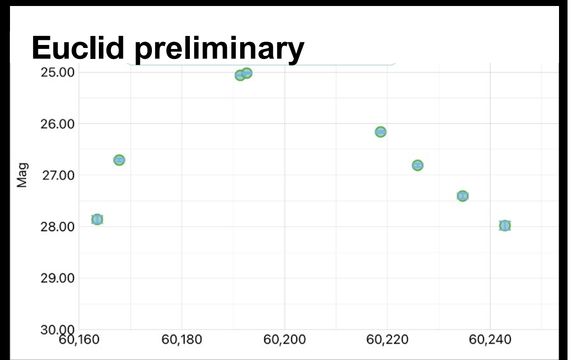






Difference images

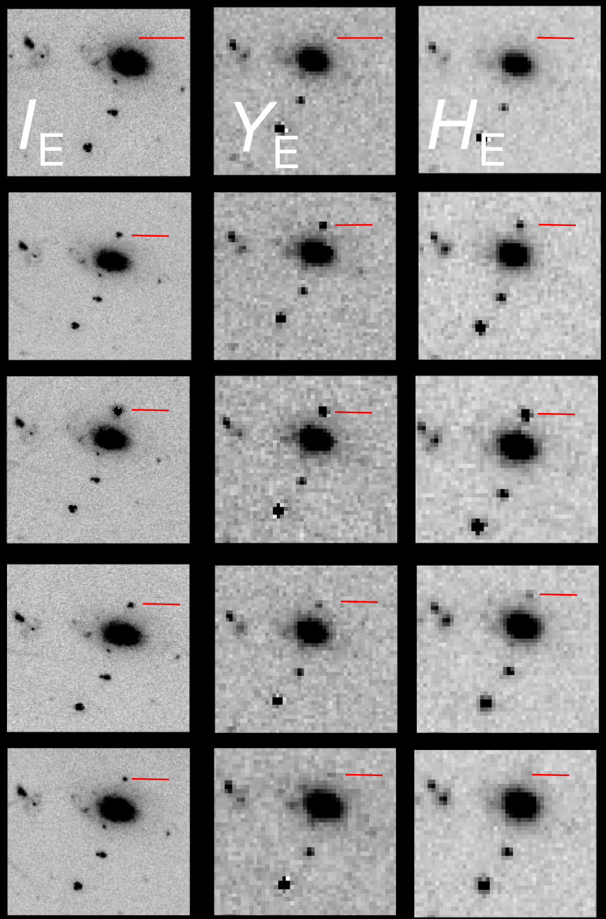


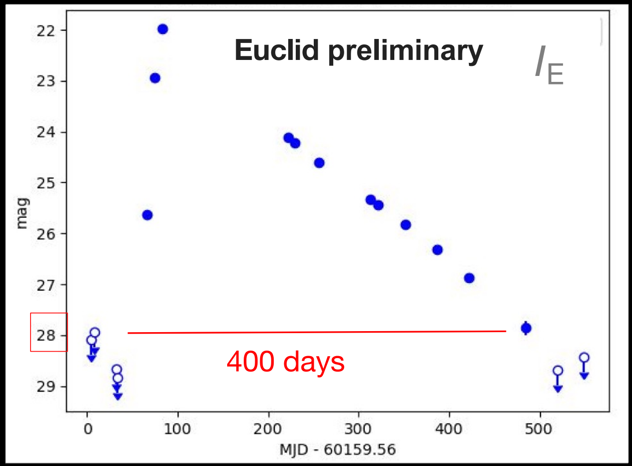


Isobel Hook, An Extraordinary Journey, Padova, April 2025

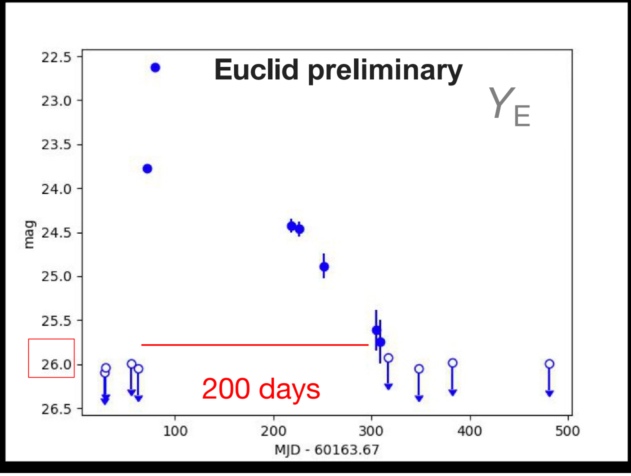
Difference Image Analysis on Euclid data

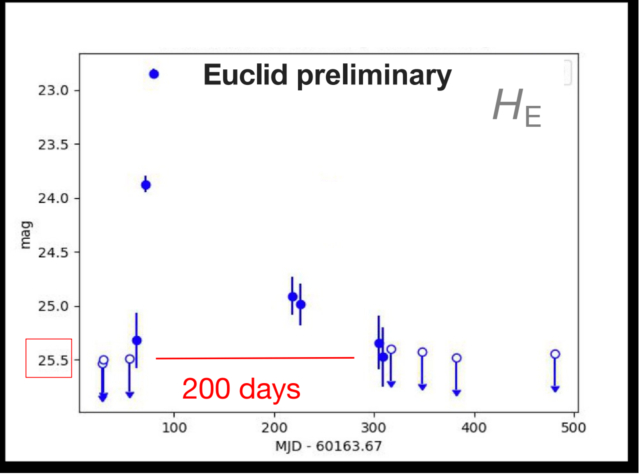
forced photometry (NIR bands)





multi-band light curves





Preliminary results

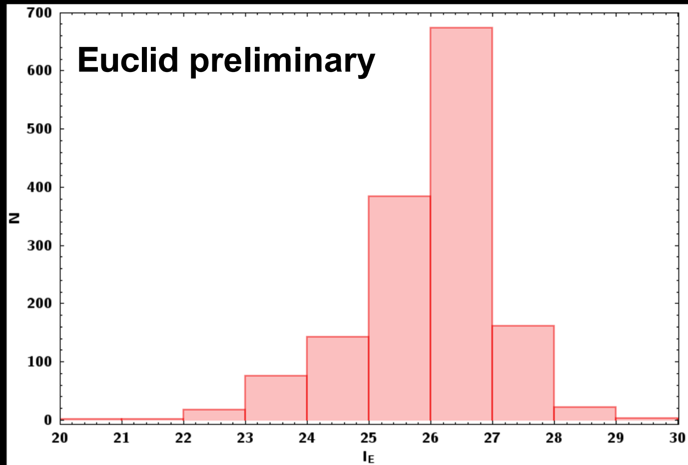
17 epochs

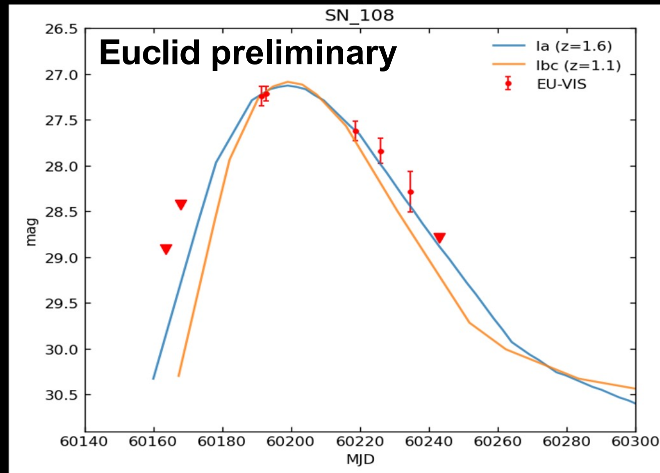
1300 SN candidates

mag limit ~27 I_E

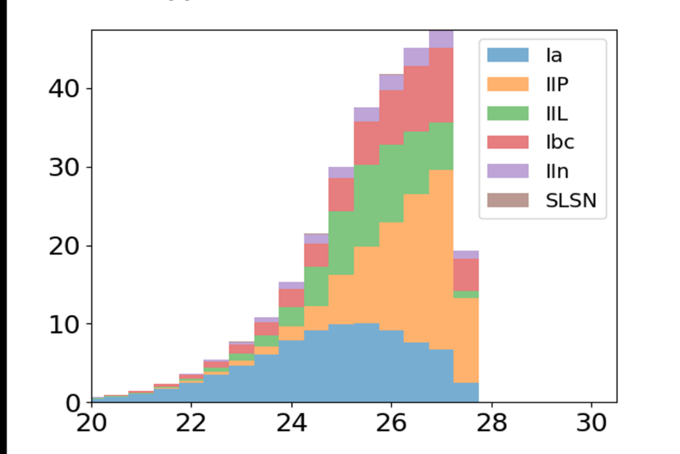
Magnitude distribution is in good agreement with simulations assuming mag limit 27.5 and 7 epochs

Photo-classification and some spectroscopic follow-up underway

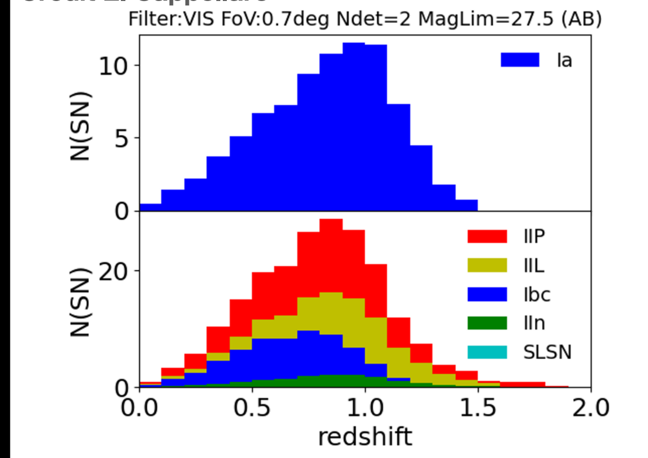




Credit E. Cappellaro

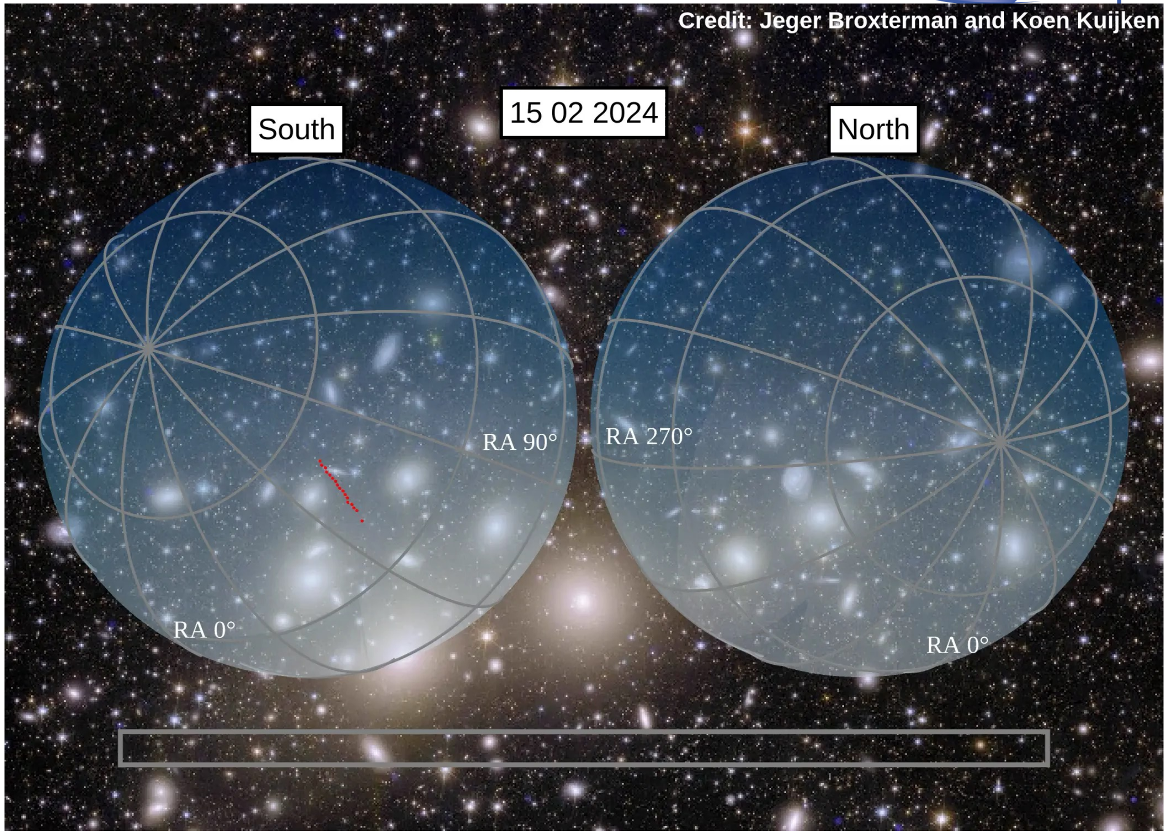


Credit E. Cappellaro



Conclusions

- Euclid is producing beautiful data
- Excellent prospects for adding value to existing transients and …
- Finding many new ones!
- Q1 public data release: https://www.cosmos.esa.int/web/euclid/euclid-q1-data-release



Above: Euclid's observing pattern. Credit: Jeger Broxterman and Koen Kuijken. Background image: Euclid's view of the Perseus cluster of galaxies, ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi

The End