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# Extragalactic transients in Euclid and new generation surveys

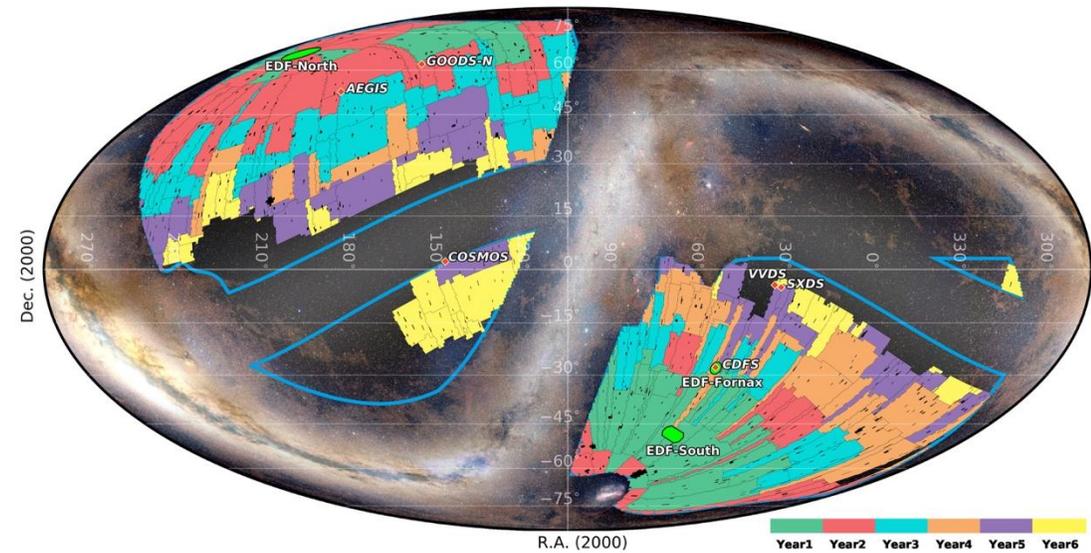
Cosimo Inserra (he/him)

Multi-Messenger Astrophysics in the Dynamic Universe | 19/02/2026



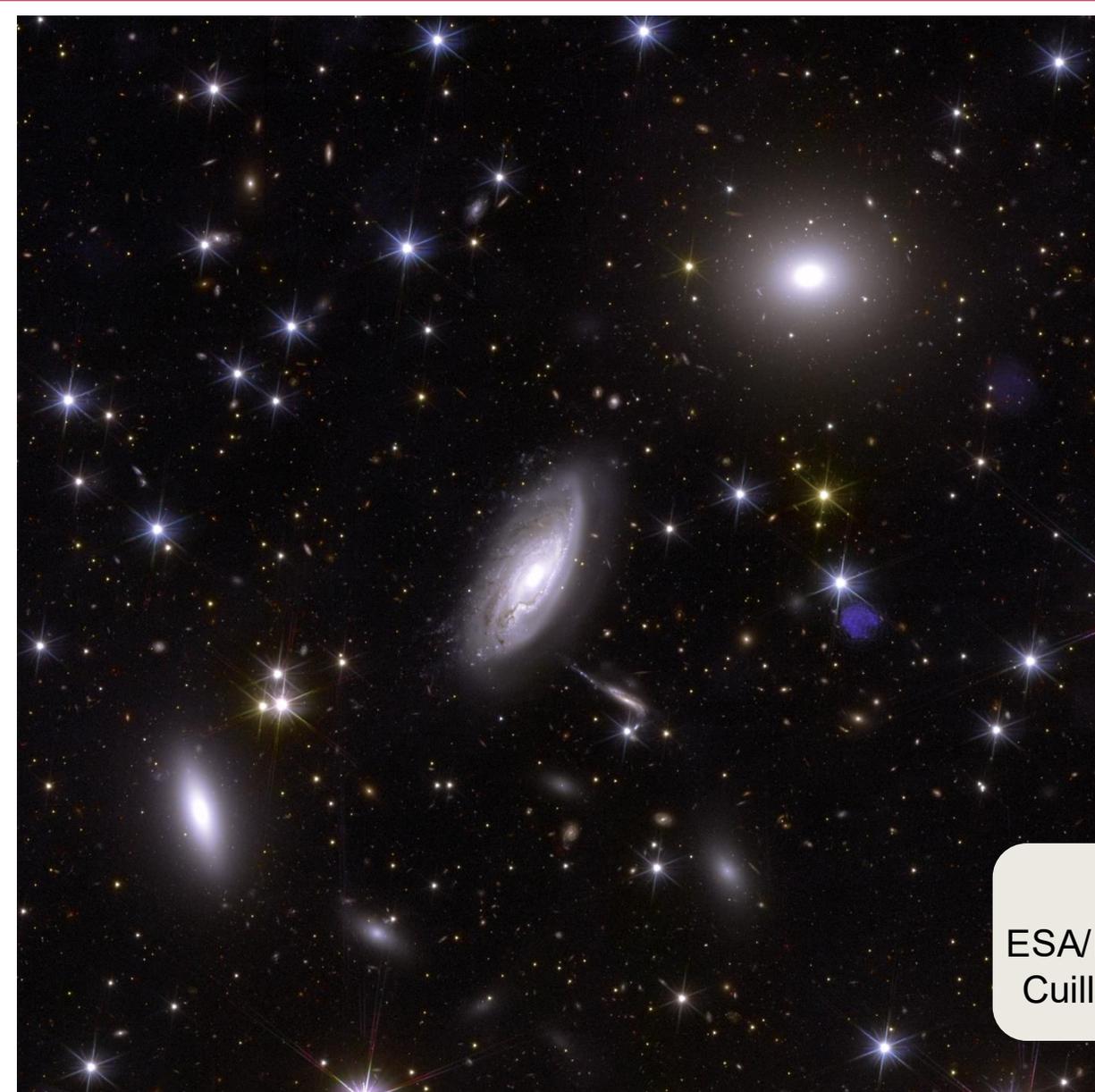
# Euclid

- 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" (0.16" FWHM)
  - NISP: Y, J & H band imager @ 0.3" (0.49" FWHM) and 920-1850nm spectrometer
- Wide Field Survey: ~ 14000 deg<sup>2</sup> single epoch over 6 years
- Deep Field Survey: 53 deg<sup>2</sup> with 6 epochs per year



(Euclid Collaboration:  
Mellier et al., 2024)

# Euclid – high resolution



## **6.6' x 6.6' Section of the Perseus cluster field**

ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi, [CC BY-SA 3.0 IGO](https://creativecommons.org/licenses/by-sa/3.0/)

# Euclid – transient science

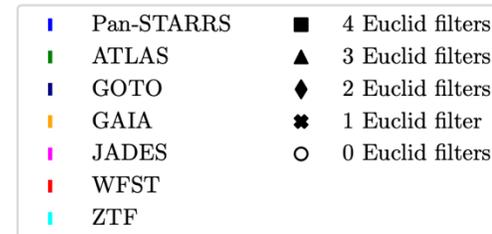
- The Euclid deep fields: good for long baseline time domain astronomy
  - Searching for (e.g.) pair instability SNe and super-luminous supernovae
  - high  $z$ , long decay
- Euclid Wide survey: well-suited to follow up of known transients
  - Including pre-discoveries!
  - Hosts of known transients

# Euclid – transient science

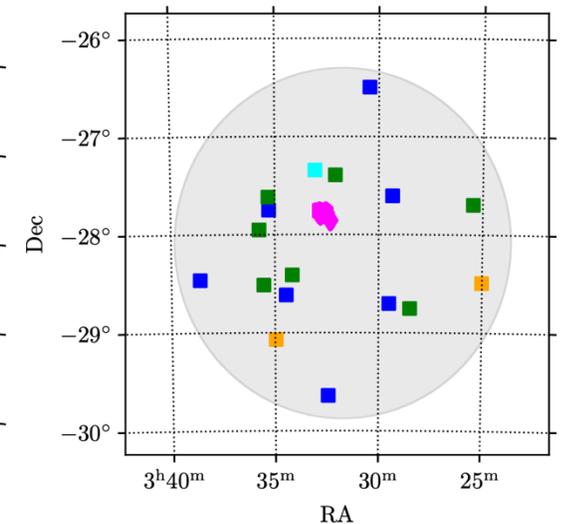
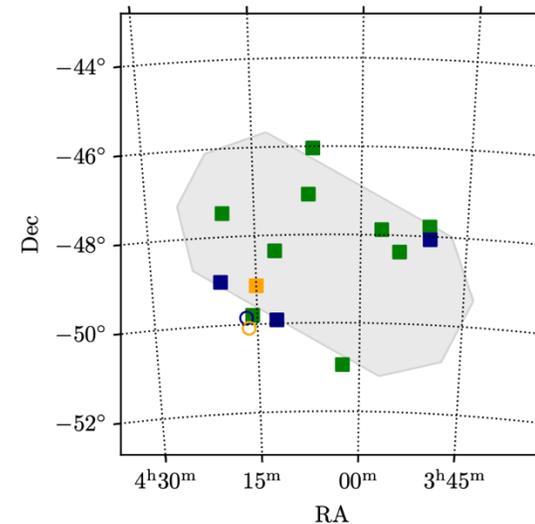
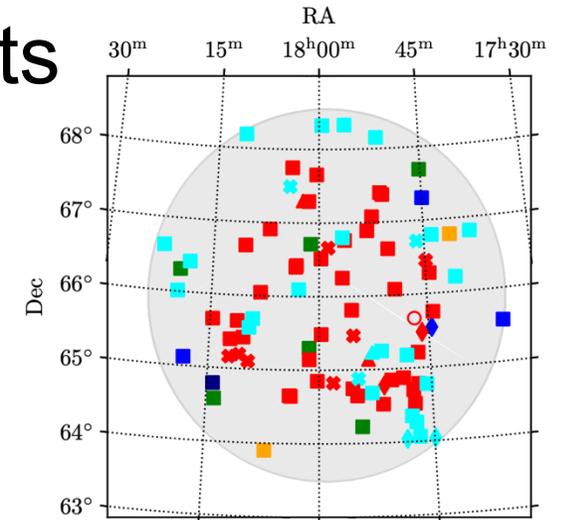
## Euclid Q1: Photometric Studies of Known Transients

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

- Goals:
  - Demonstrate the capability of Euclid for transient science
  - Add scientific value to known transients from NIR filter
- Euclid data: a single pass of the deep fields
  - taken July-September 2024
- Selected known transients in the Q1 fields
  - from 1 year prior to Q1 observations and up to 05/12/24
  - from 3 years prior *AND* discovered brighter than 18th mag
- 164 transients from TNS met these criteria

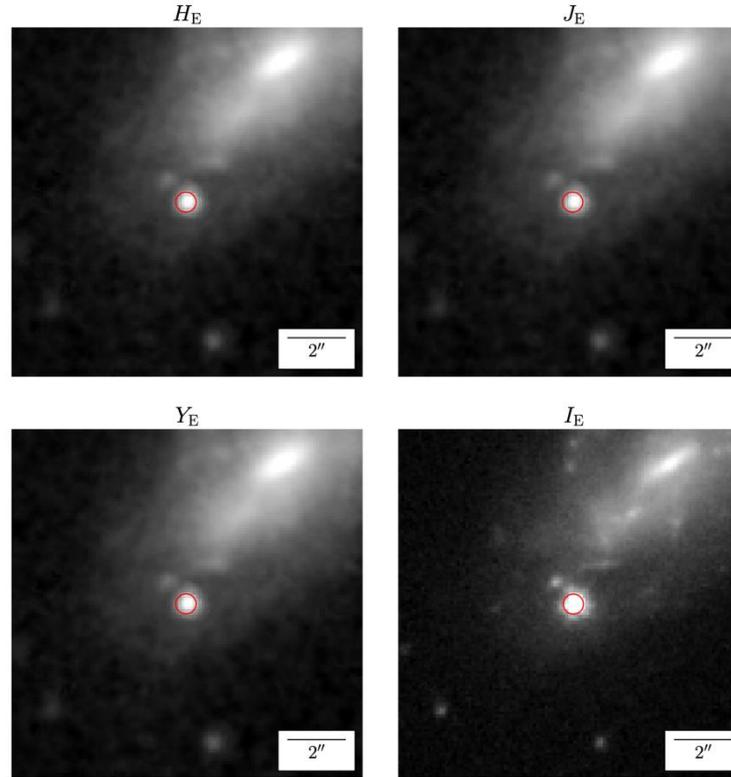


Duffy et al. 2025

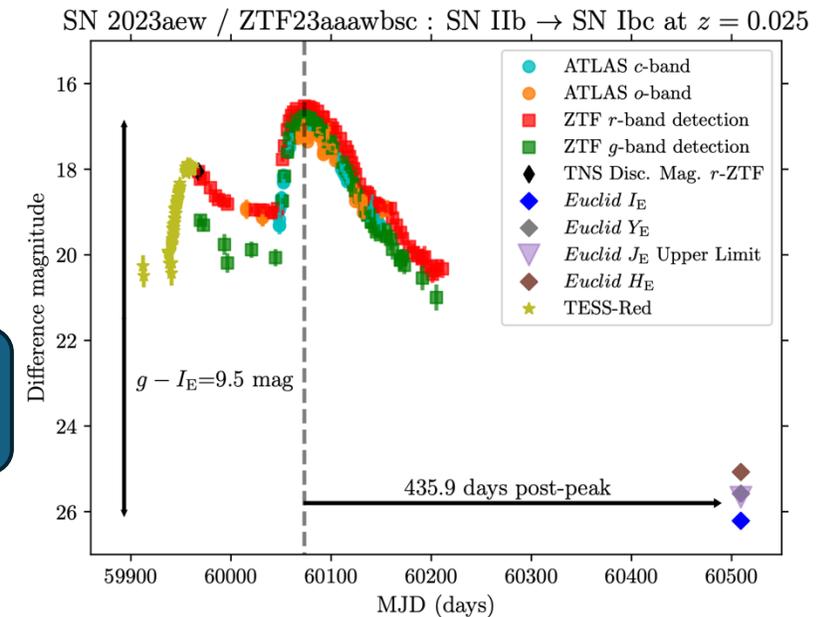
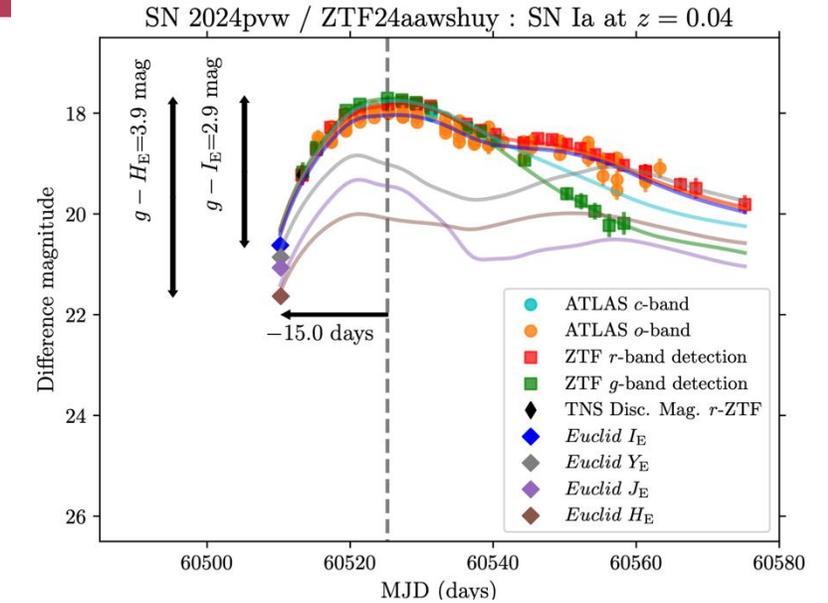


# Euclid – transient science

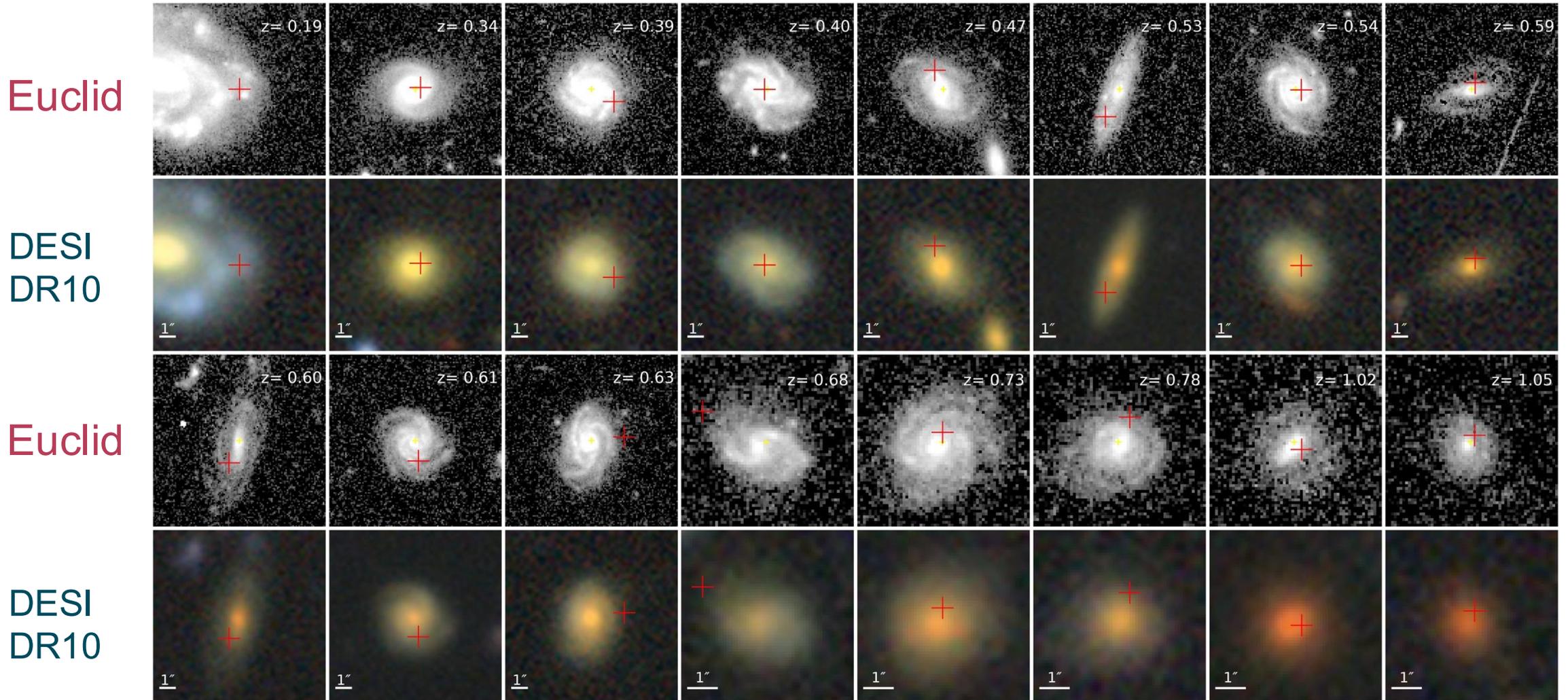
- Euclid goes much fainter than the discovery surveys
- Early and late detections possible
  - constrains progenitors, explosion physics and environment
- Detections for 61% of transients discovered with  $< 24$  mag in the year before Euclid observations
  - Rising to 82% within 100 days
- Caveat: no reference images



Almost simultaneous VIS and NIR, e.g. AT 2024pnv



# Euclid – host science

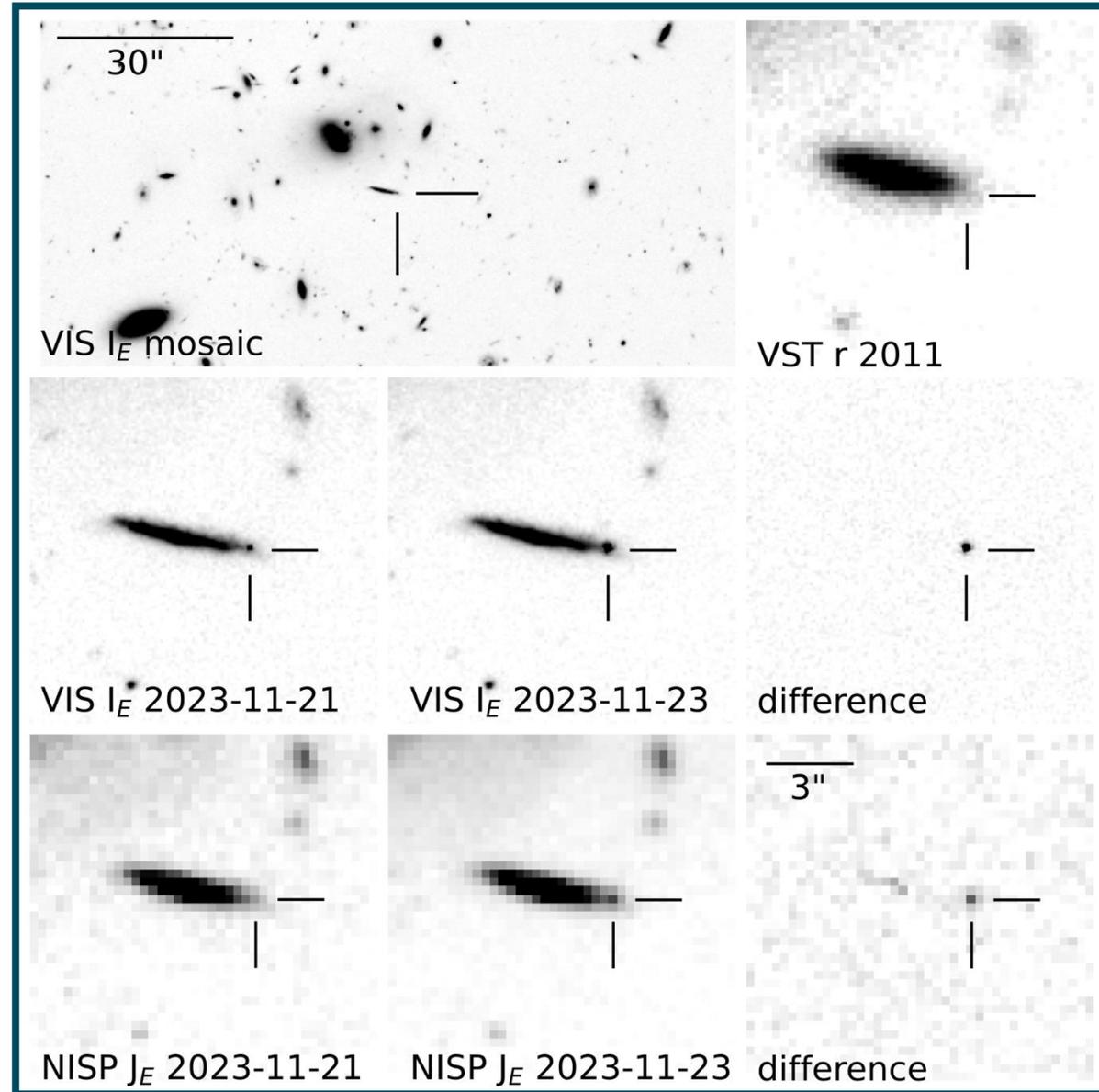


Euclid images from the Q1 public data release (EC: Aussel et al 2025). Image credit: Isobel Hook

# Euclid – transients pipeline

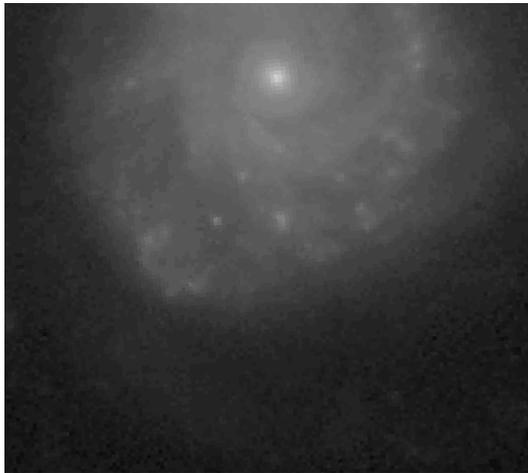
- Raw image reduction...
  - Cosmic ray removal
  - Astrometric and photometric calibration
  - Stacking
  - Difference imaging
- PSF and forced photometry
- VIS and NISP light curves

AT2023adqt (Euclid 1. Overview of the Euclid mission, Euclid Collaboration: Mellier, 2024)



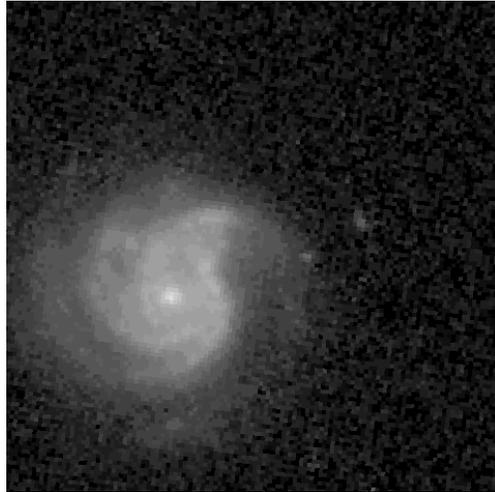
# Euclid – transients pipeline

Some multiple detections by Euclid

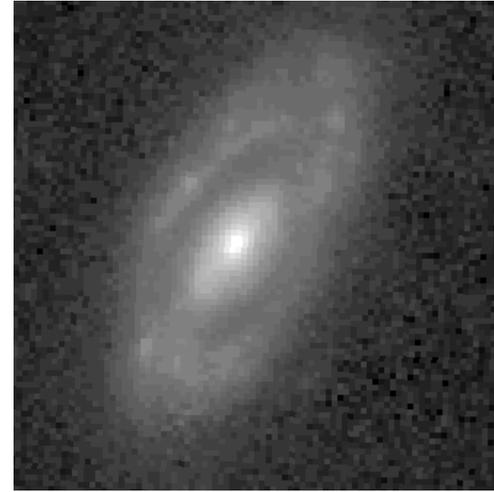


202pww  $z_{gal}=0.04$

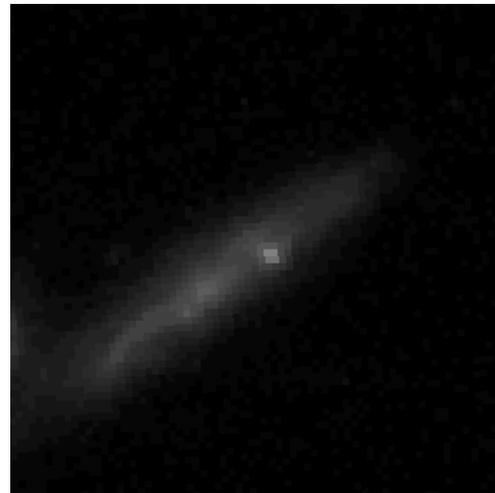
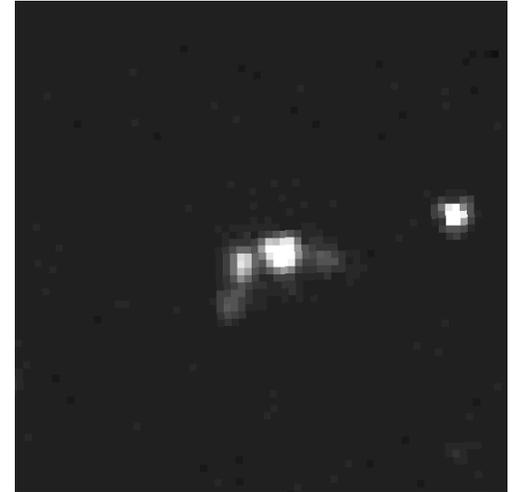
2024tdr  $z_{gal}=0.291$



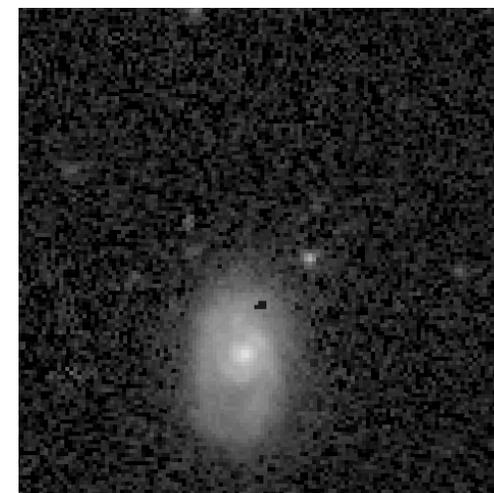
2024zin  $z_{gal}=0.327$



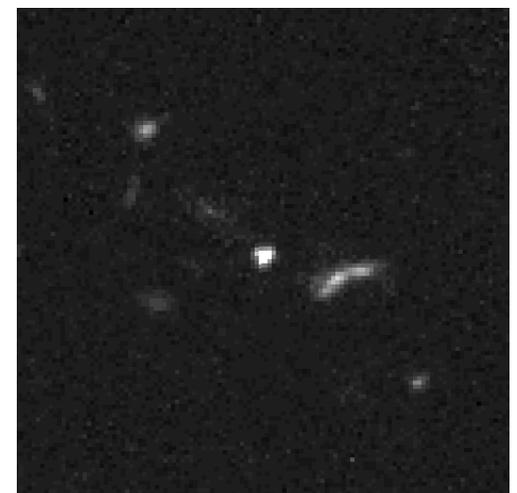
2024tli  $z_{gal}=0.828$



2024tql  $z_{gal}=0.332$



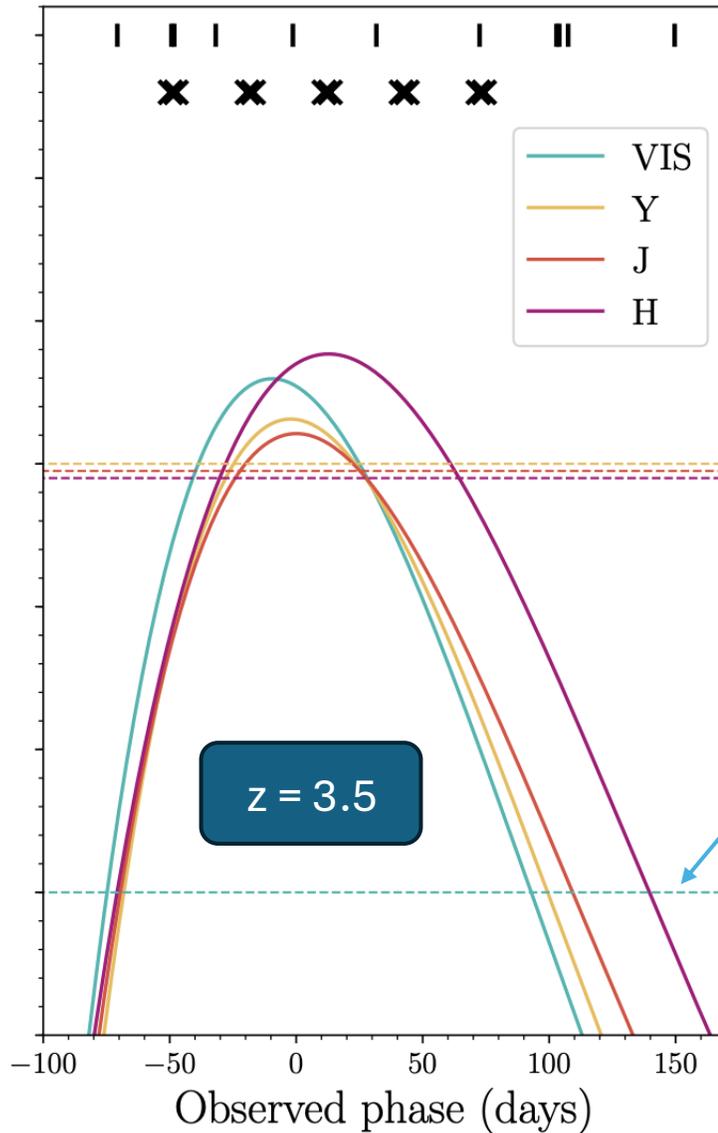
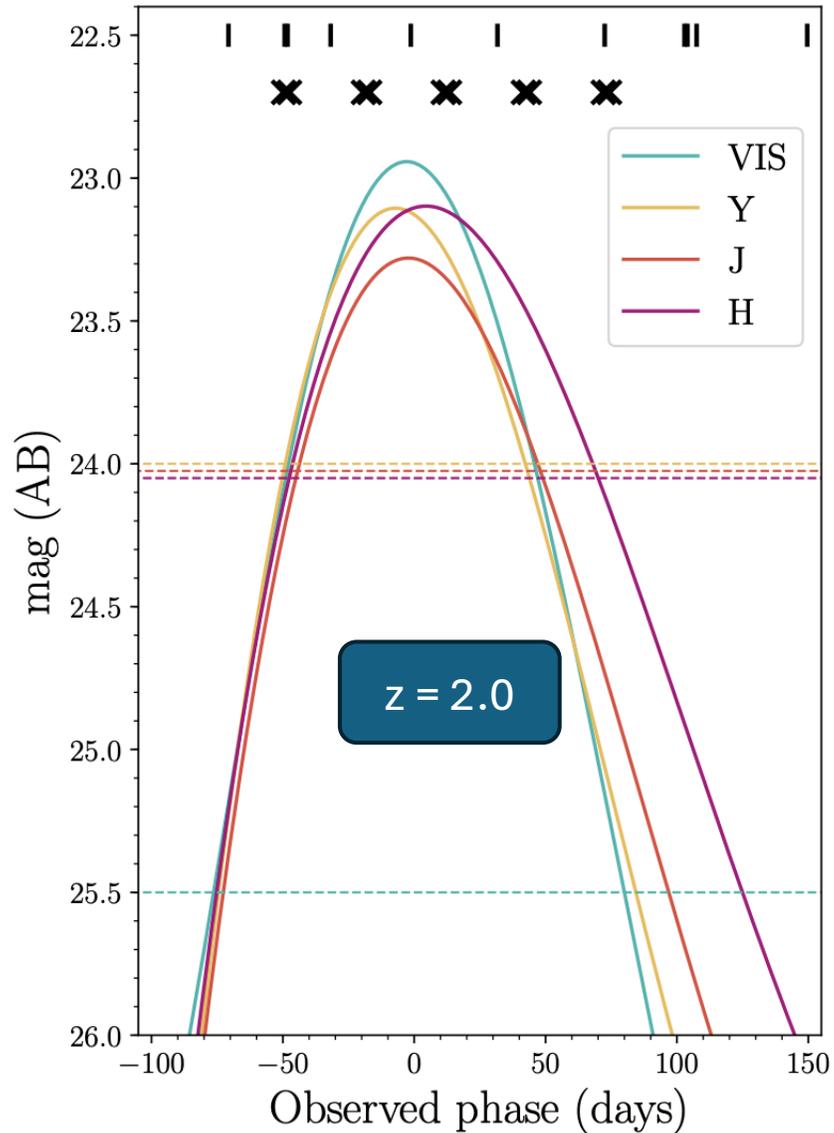
2024tix  $z_{gal}=0.357$



2024zjh  $z_{gal}=1.149$

Euclid DR1 preliminary  
Animations credit: Isobel Hook

# Euclid – Superluminous Supernovae



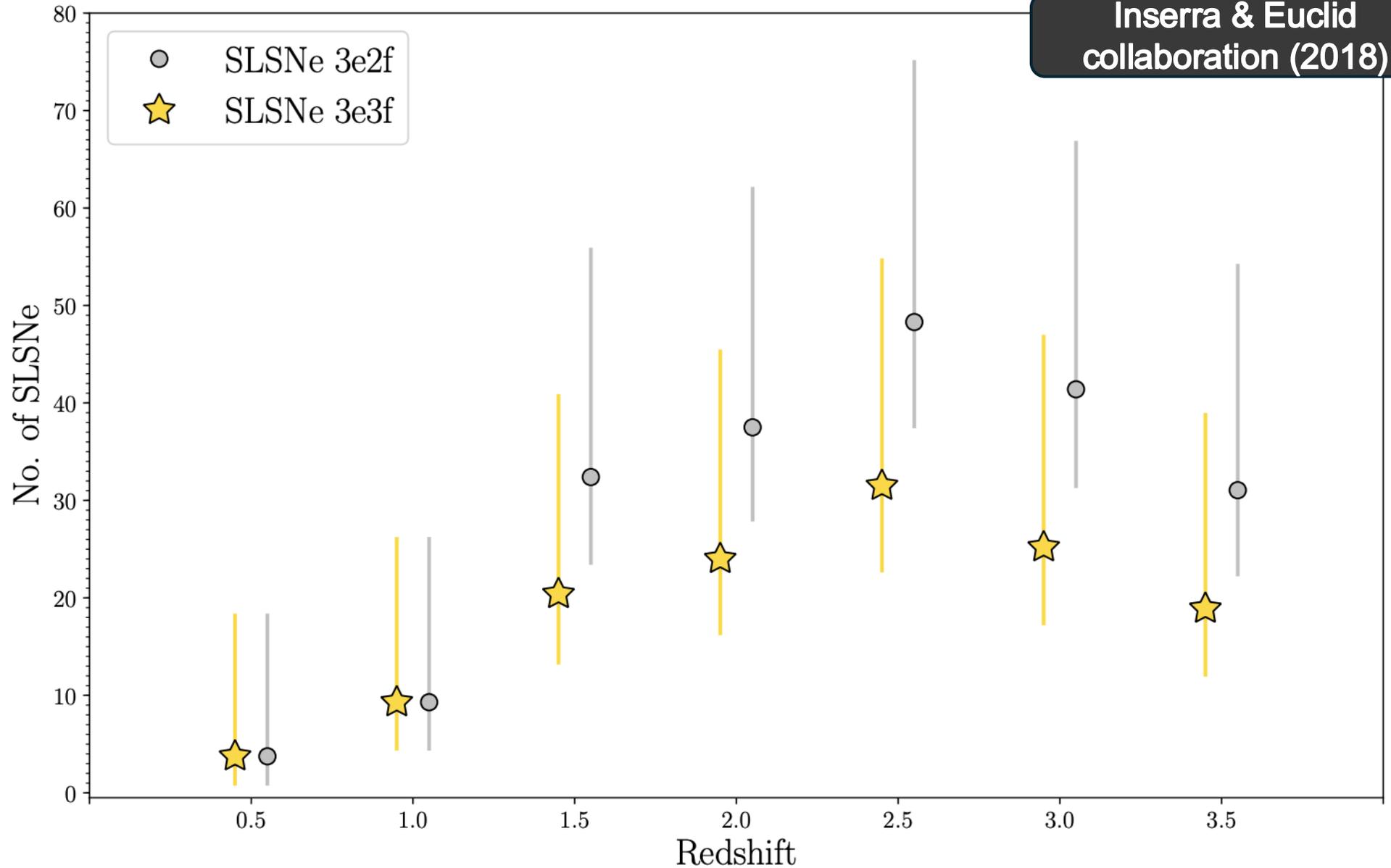
5 $\sigma$  limit

Inserra & Euclid  
collaboration (2018)

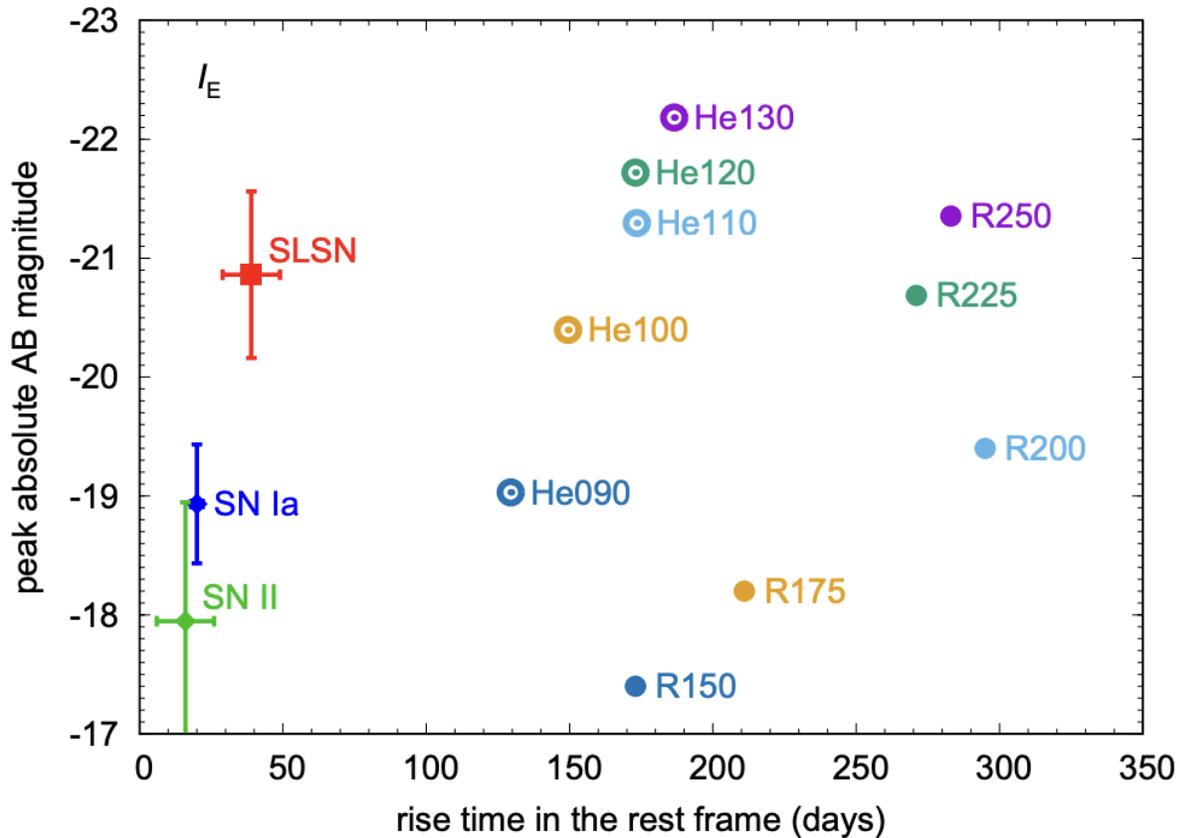
# Euclid – Superluminous Supernovae

140 (gold sample)  
210 (silver sample)

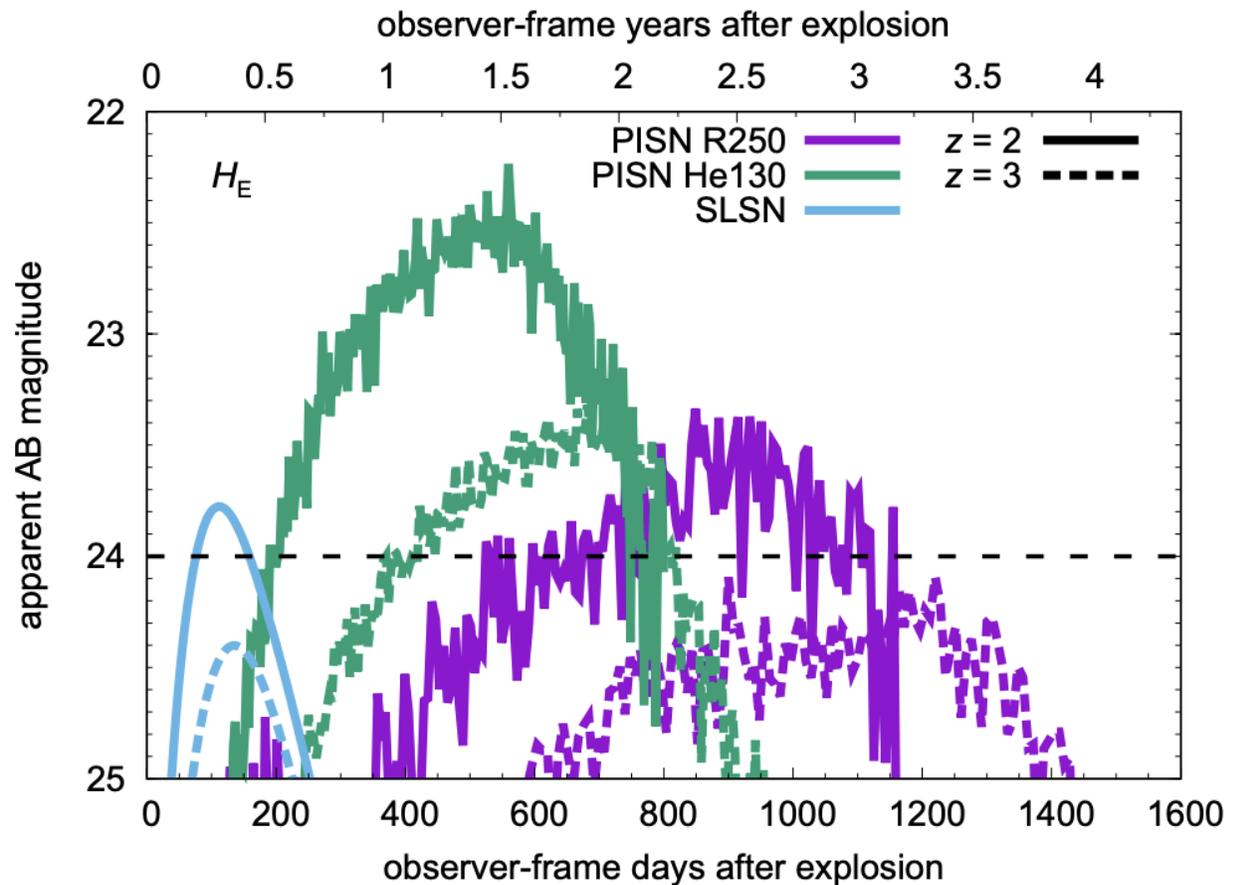
- Star formation
- Galaxy population
- Interstellar / intergalactic medium
- Cosmology?



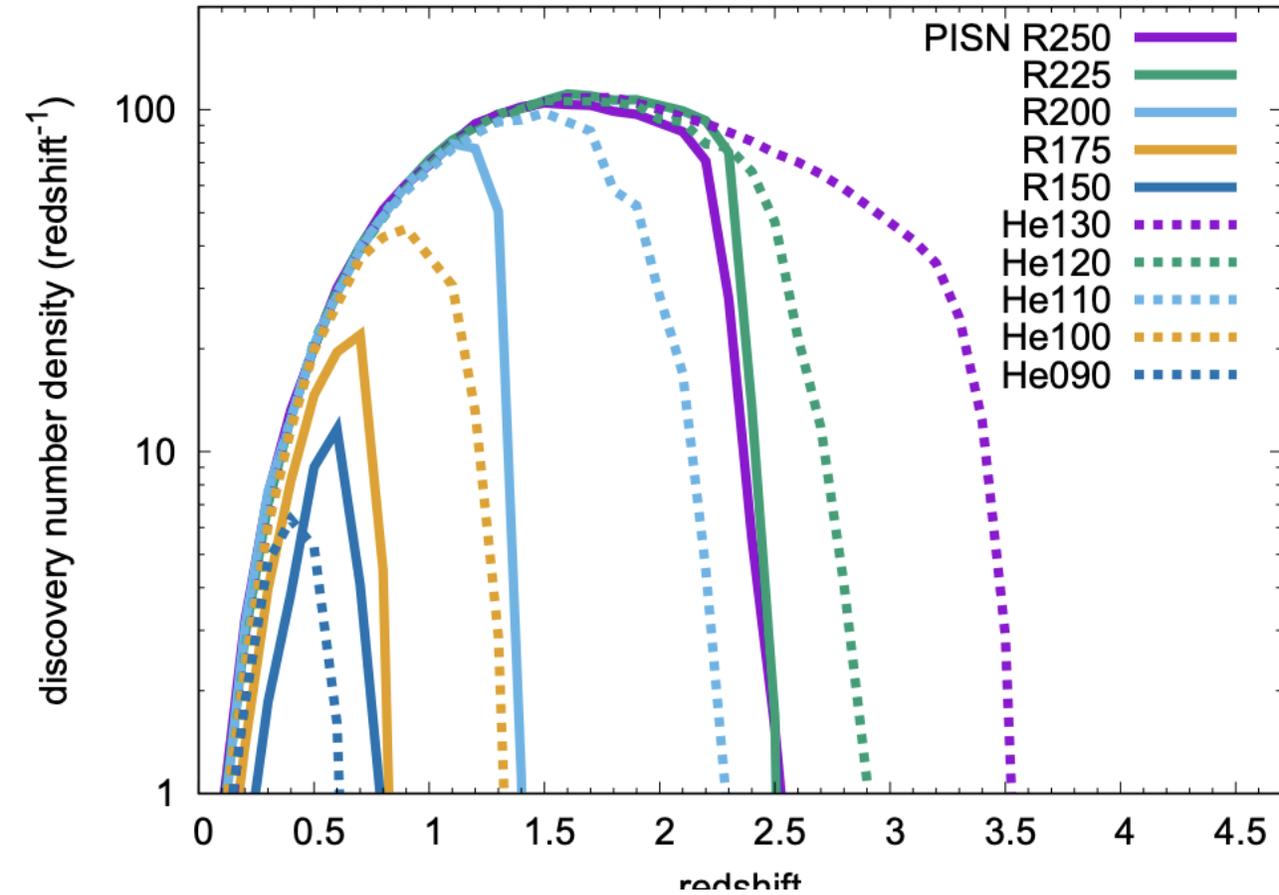
# Euclid – Pair Instability Supernovae



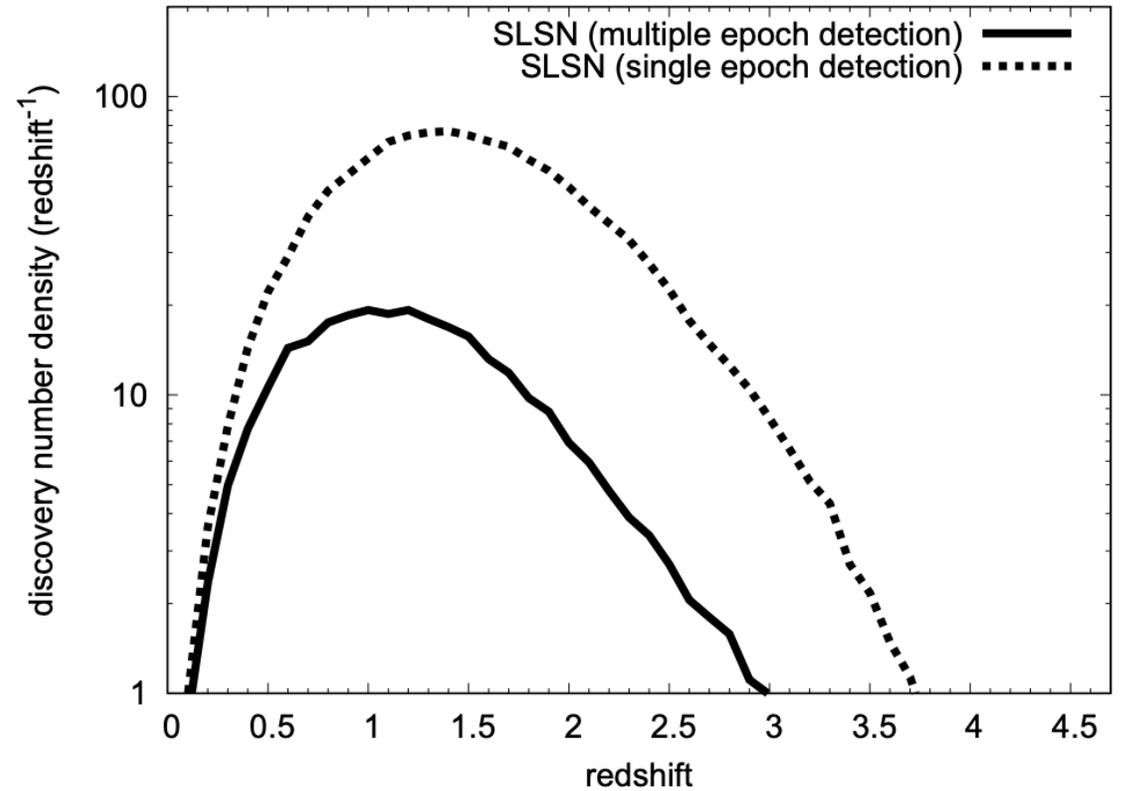
Moriya & Euclid collaboration  
(2022)



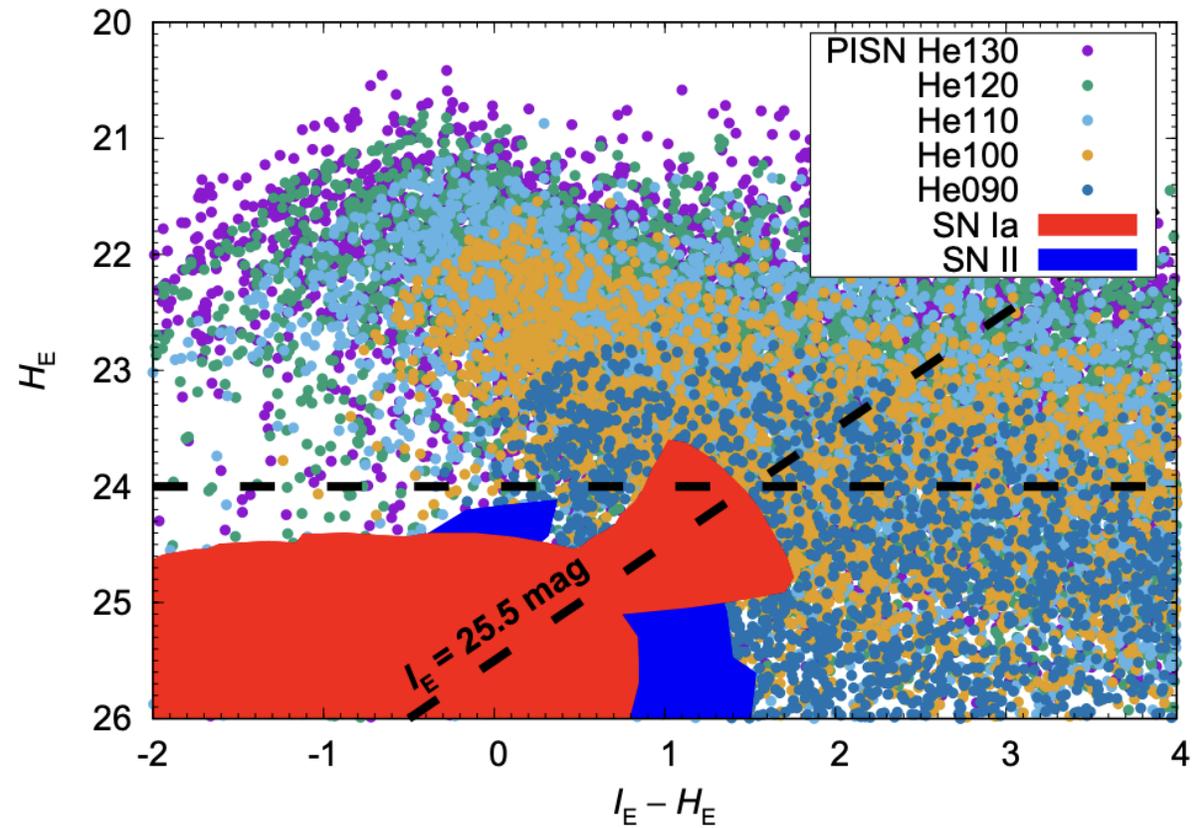
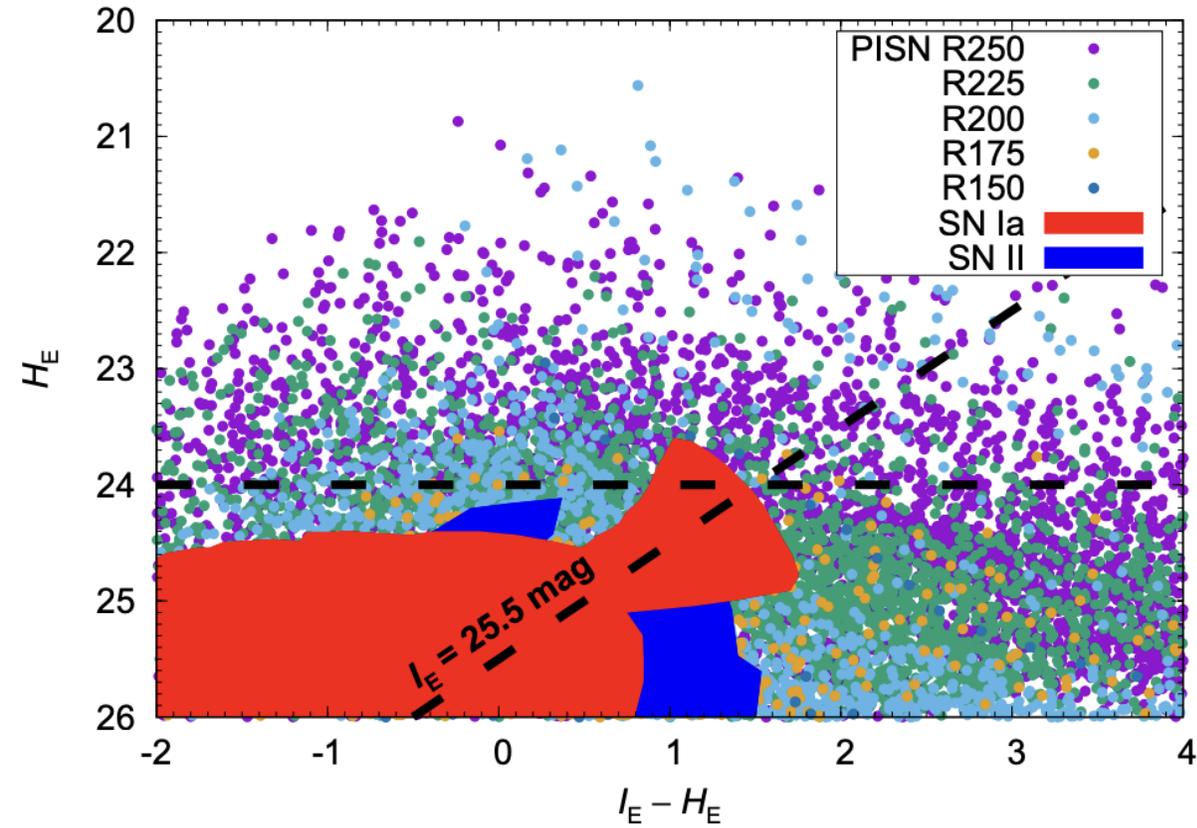
# Euclid – Pair Instability Supernovae



Moriya & Euclid collaboration  
(2022)

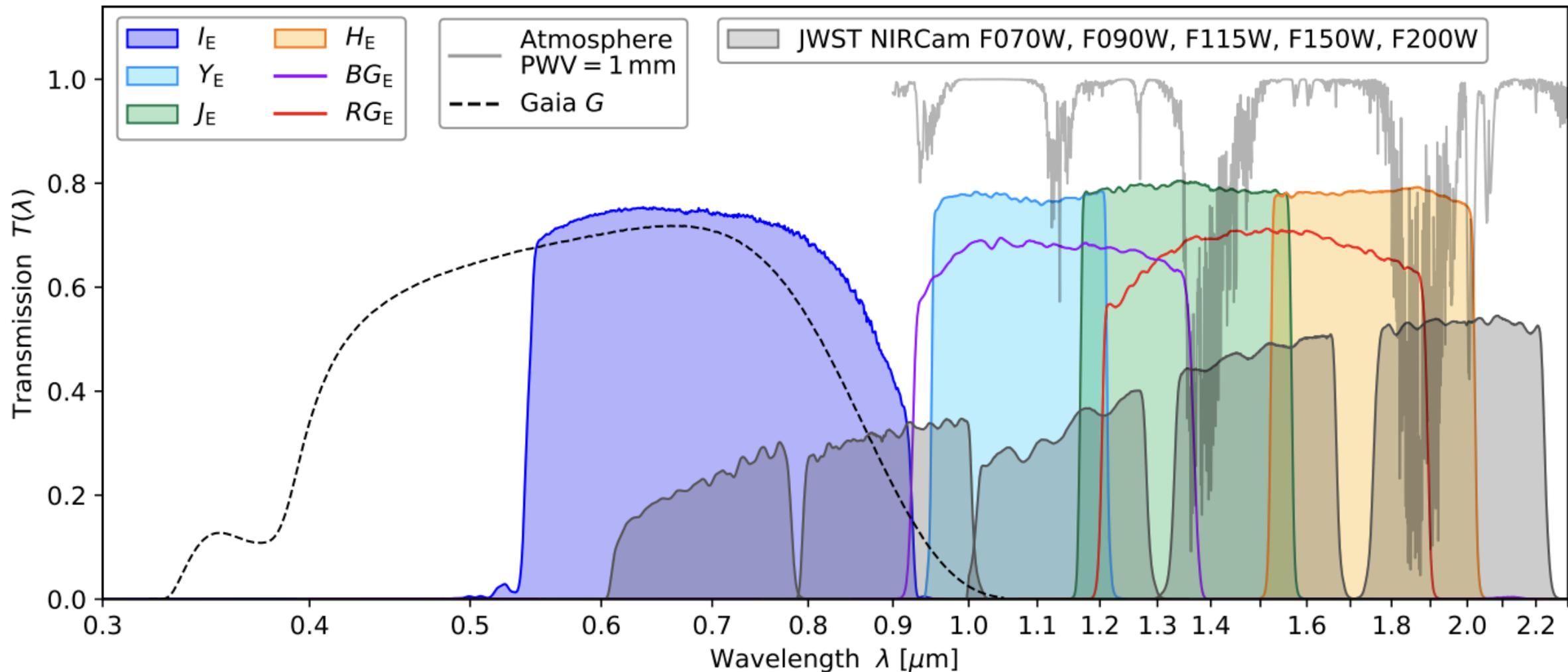


# Euclid – Pair Instability Supernovae



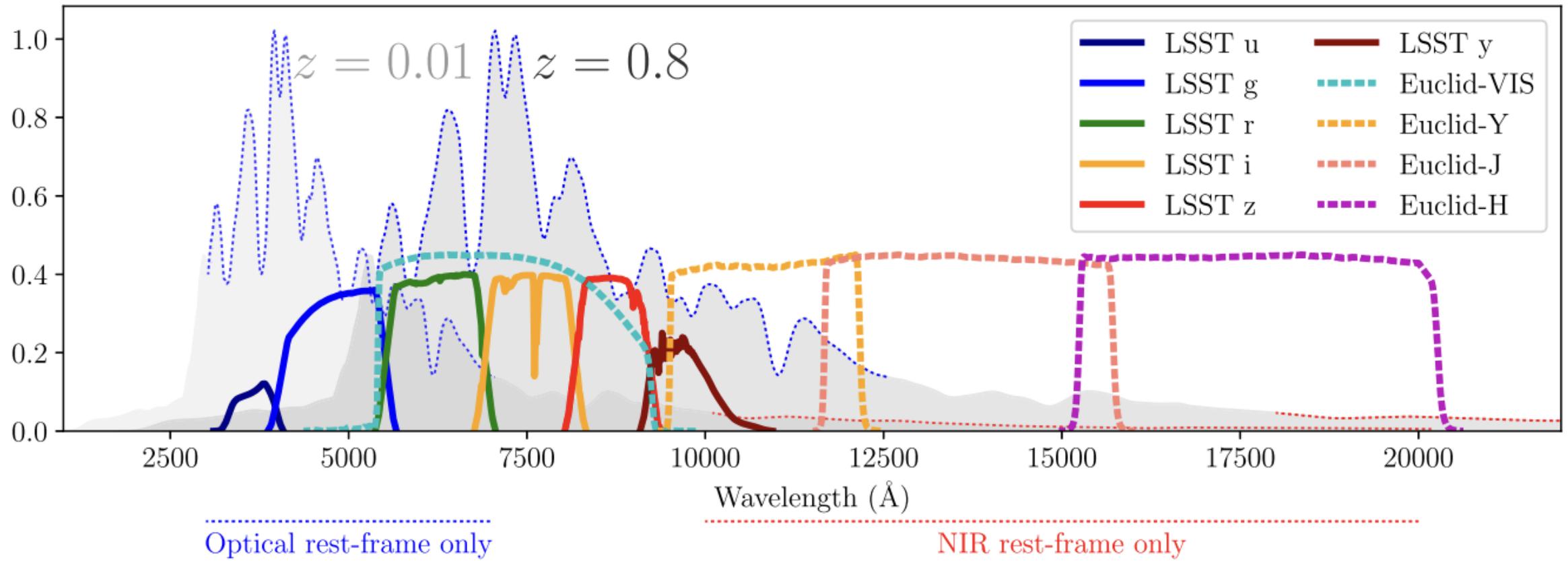
Moriya & Euclid collaboration  
(2022)

# Euclid – synergies



Euclid I, Mellier & Euclid Coll (2024)

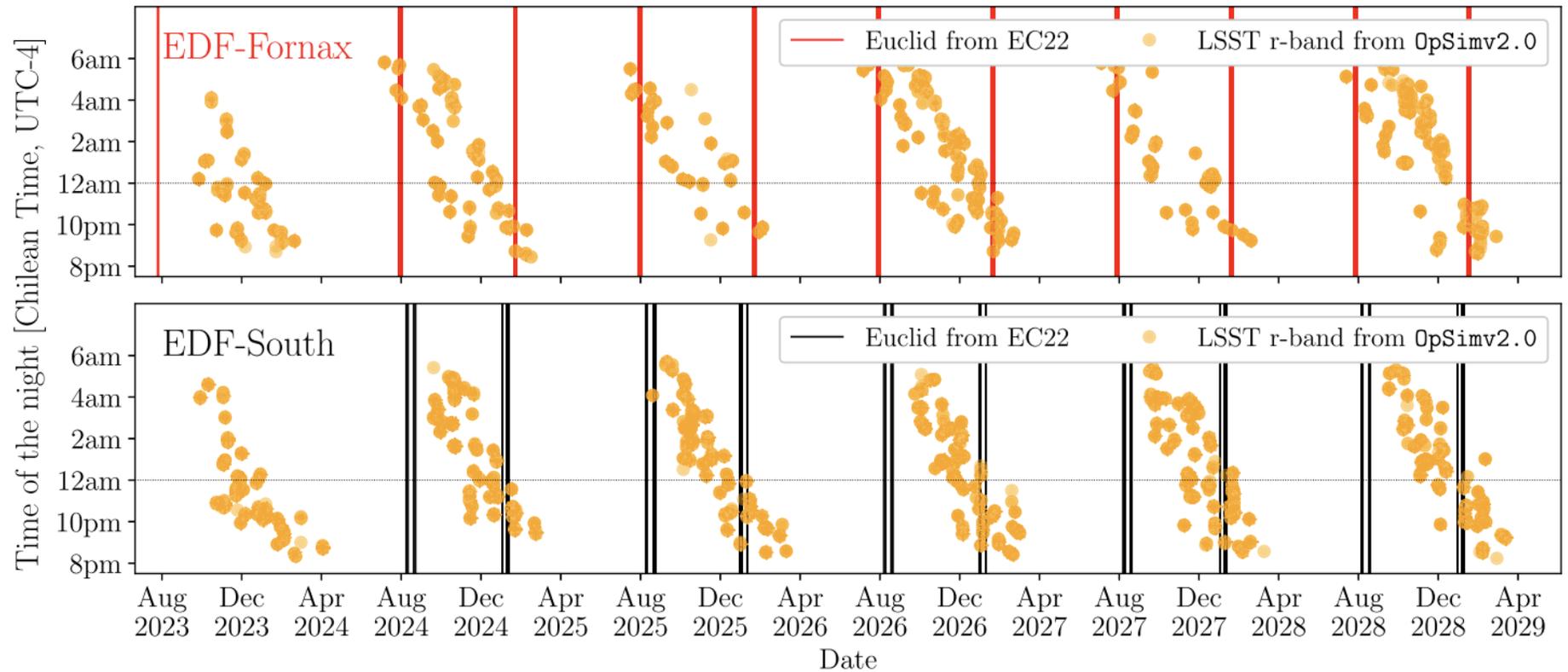
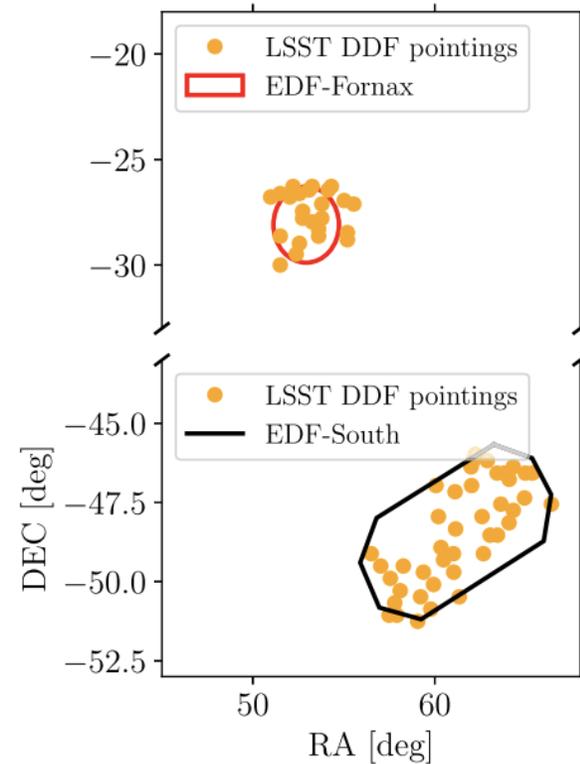
# Euclid – synergies



Bailey et al. (2023)

# Euclid – synergies

6 consecutive nights every 6 months



Bailey et al. (2023)

3-4 times over 13/14 days  
every 5 and 7 months

# Euclid to Rubin (LSST)

- Matching a stream of **Lasair** alerts to Euclid observations within  $\pm 60d$
- $>10,000$  matches so far (many upper limits)
- Euclid images gathered and aperture photometry performed
- Matched alerts are presented on a web app
- Users can look back on longer time scales
- Will soon switch from ZTF stream to LSST!

Duffy et al. submitted

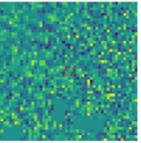
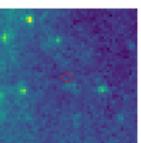
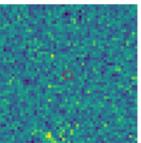
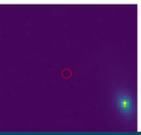
### Latest Matched Alerts

0 60

Observation Overlap (days)

0 60

25 entries per page Search: SN

Alert Name	Coordinates	Lasair Alert Date	Euclid Observation Date	Sherlock Classification	Euclid Cutout
<a href="#">ZTF24abuswmo</a>	169.296 77.3735	30-11-2024 09:11:55 2 days, 6 hours ago	18-10-2024 08:10:37 1 month, 2 weeks ago	SN	
<a href="#">ZTF24aburrkf</a>	130.908 65.1844	30-11-2024 07:11:59 2 days, 8 hours ago	12-10-2024 22:10:21 1 month, 2 weeks ago	SN	
<a href="#">ZTF24abuhays</a>	165.565 75.7575	26-11-2024 13:11:23 6 days, 1 hour ago	20-10-2024 12:10:07 1 month, 1 week ago	SN	
<a href="#">ZTF24abuhavw</a>	166.552 75.1532	26-11-2024 13:11:04 6 days, 1 hour ago	22-10-2024 10:10:35 1 month, 1 week ago	SN	

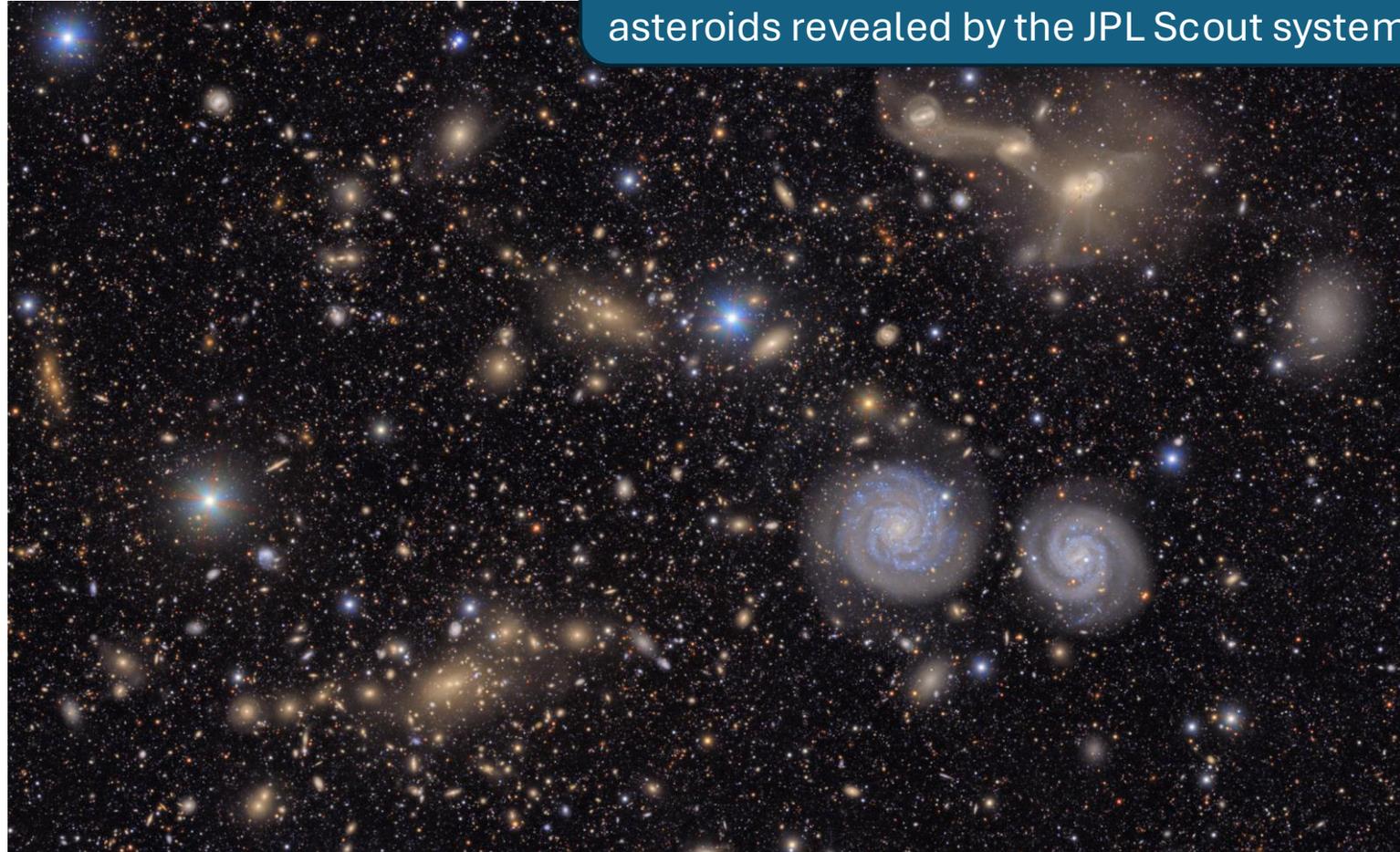
# Rubin/LSST era

Starting formal operation on March 2026 (maybe)

- 1M SNe per year
- 250k SNe Ia per year
  - 44 strongly lensed SNe Ia per year
- 100k+ CC SNe
- ~3000 SLSNe
- Hundreds of precursors

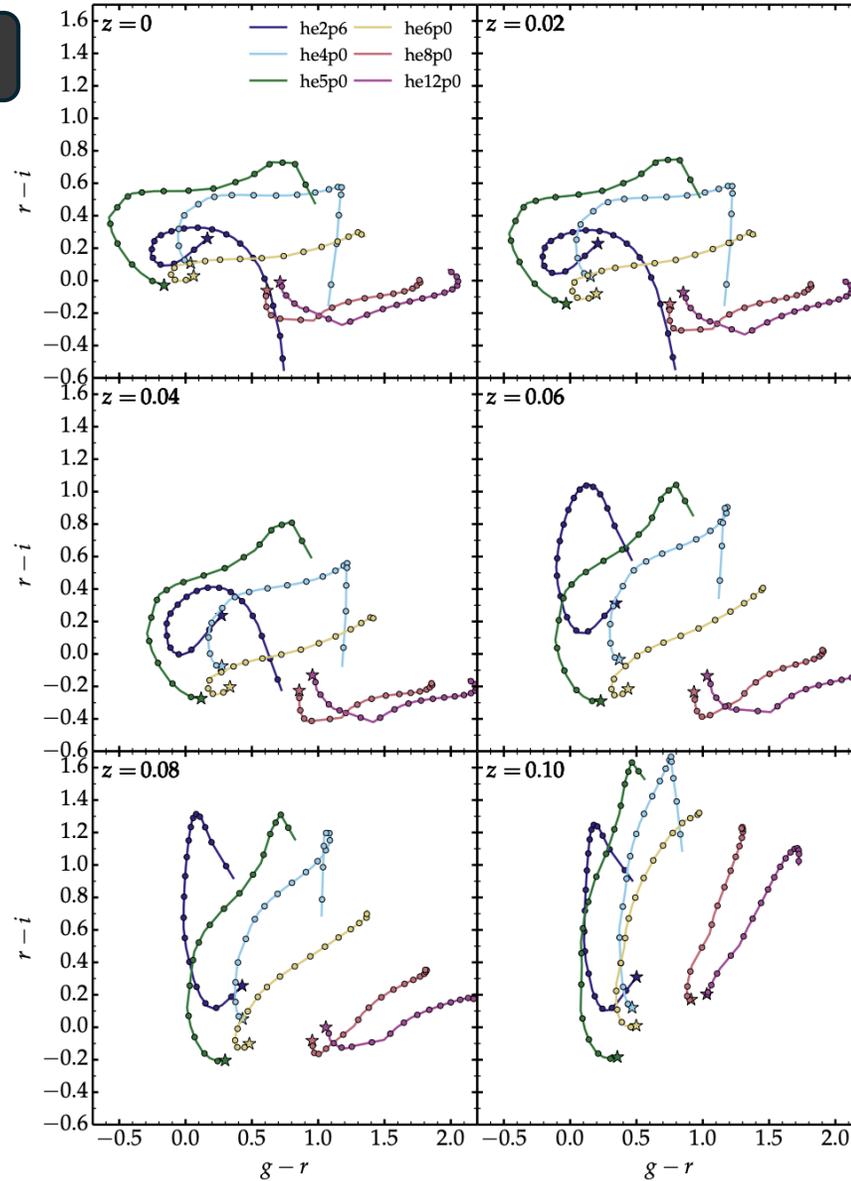
49 full-moons of sky in a single frame

3% on ToO triggered by LIGO/Virgo/KAGRA array, IceCube, and potentially hazardous asteroids revealed by the JPL Scout system



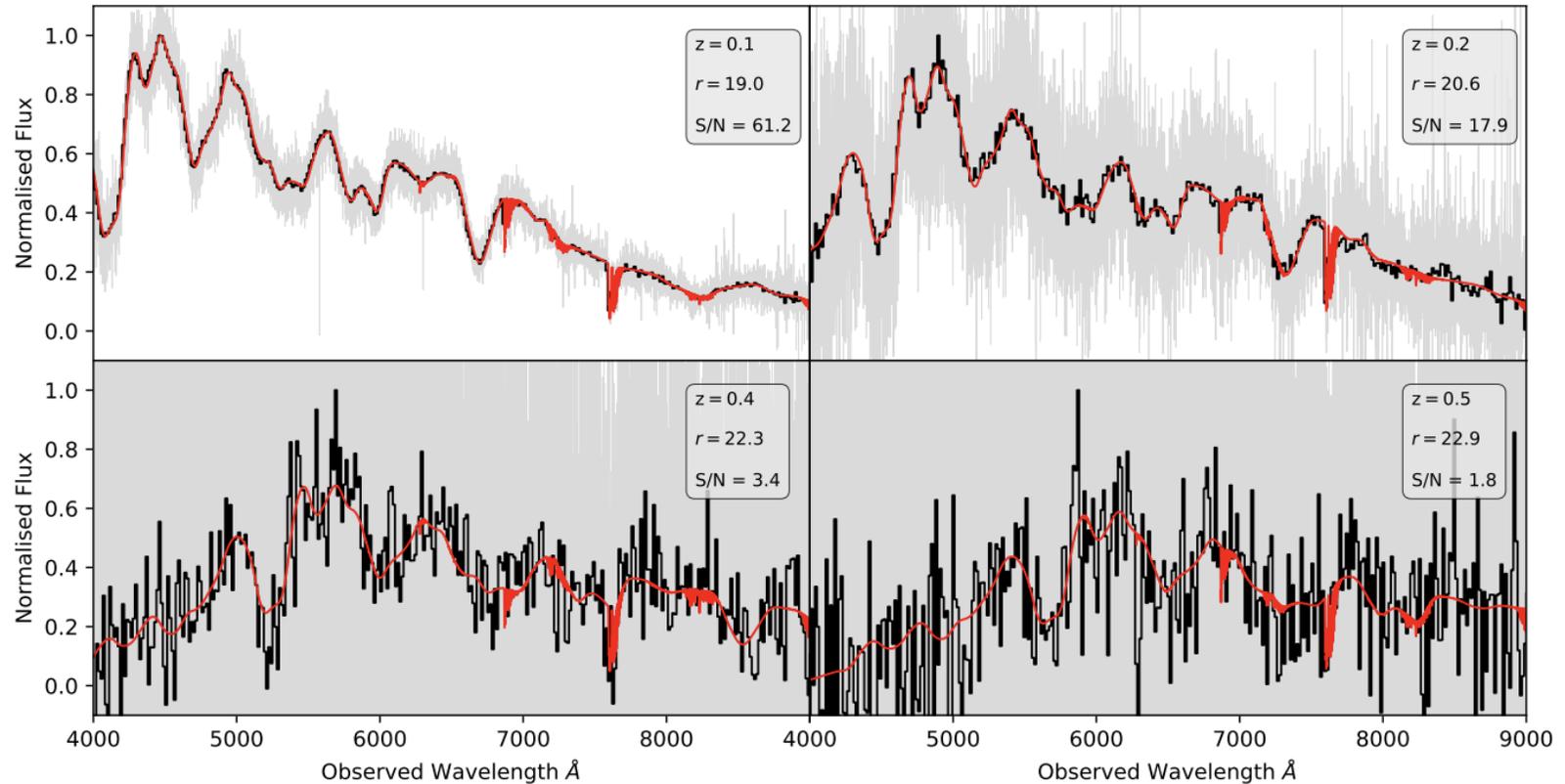
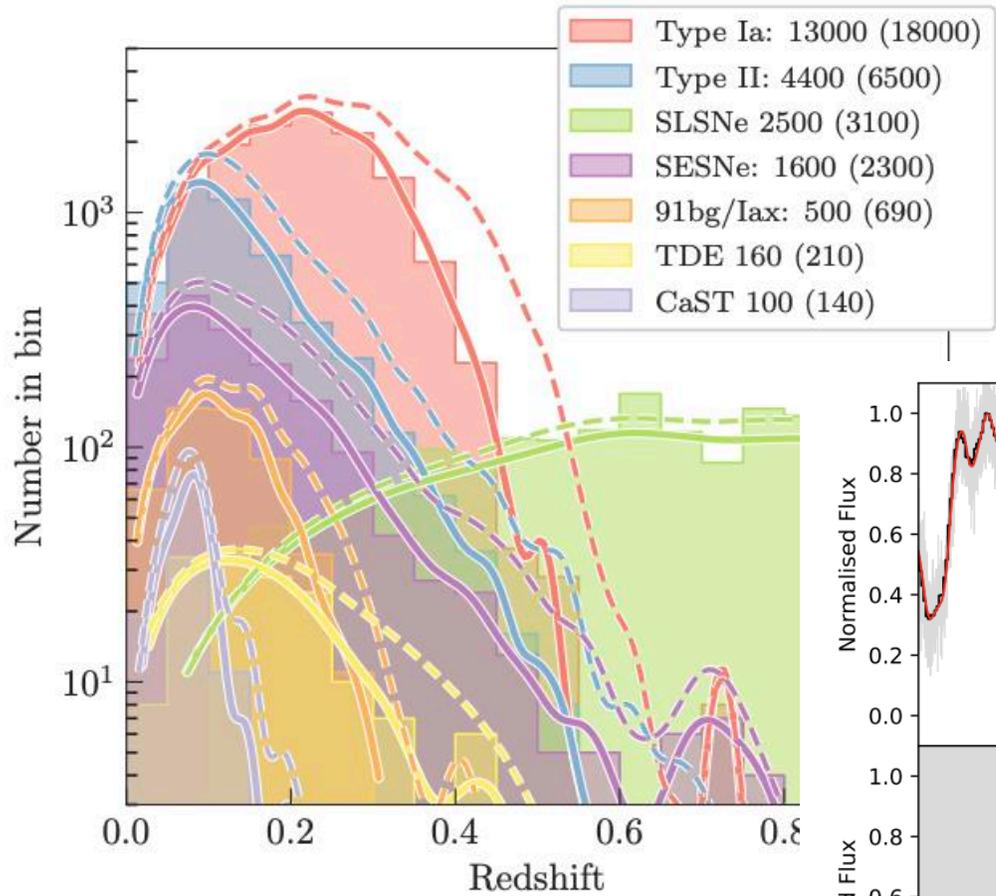
# Rubin/LSST era

Dessart et al. 2022



+ Steve Schulze talk

# LSST + 4MOST/TiDES



# LSST + RISOTTO



## Rubin-ESO Investigative Spectroscopy Of Target Transient Objects (167 hrs @ VLT per year – Xshooter and FORS2)

- (1) What is the population of low luminosity (absolute magnitude  $> -13$ ) transients in nearby galaxies? (i.e. failed supernovae, stellar mergers, low energy core-collapse and electron capture supernovae, non-terminal outbursts from massive stars, and supernova precursors)
- (2) What are the progenitor systems of Type Ia supernovae, what causes the faintest Type Ia explosions, and how can late time emission reveal interaction between ejecta and circumstellar matter?
- (3) How are core-collapse supernovae affected by metallicity, and can we use them to measure cosmologically useful distances?
- (4) What powers superluminous supernovae, and what can they reveal about the first generations of stars in the high-redshift Universe? Do the long-sought after pair instability supernovae exist, or do the most massive stars meet a different fate?
- (5) What is the population of supermassive and intermediate mass black holes in the Universe, and how do tidal disruptions of stars enable us to study black holes that are not actively accreting?
- (6) What are the unknown classes of transients that are yet to be revealed by Rubin?

# LSST + RISOTTO

It increase of horizon distance by a factor of 5  
(volumes increases by a factor of 125)

