A precursor Euclid survey of the Roman microlensing fields

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Cosmic shear and microlensing, EU side

- 2002 Bennett & Rhie space based microlensing
- 2004-2005 : Cosmic shear and microlensing from Dome C ?

  Beaulieu and Mellier -> after all, not realistic, so no papers about it

  Bennett, Gaudi et al. advocating for space based microlensing, GEST

- 2007 ESA DUNE proposal (3 months of microlensing)

  « Everything that is good for cosmic shear is good for microlensing »

- Microlensing program on board Euclid since 2008 (*additionnal science*)
- 2010 Decadal survey with WFIRST (now Roman Space Telescope).

- Thesis of Matthew Penny: simulations for Euclid 2012.
- First Roman microlensing simulations based on work by Matthew Penny done for Euclid
- Euclid exoplanet working group, current leads Kerins, Osorio Zapatero, Penny
- 2021-now, exploring survey of Roman fields and simultaneous observations

Microlensing remained as « additional science » in Euclid, while becoming « core science » for Roman

Satellite

- Launcher: SpaceX Falcon 9 from Cape Canaveral
- Orbit: Sun-Earth Lagrange point 2 (L2)

Telescope

- Type: Korsch off-axis three mirror anastigmat; Silicon Carbide telescope
- Aperture: 1.20m diameter primary mirror,
- Focus: 24.5m focal length; paraxial F-number F/20.42
- Dichroic element: reflected beam to VIS, transmitted beam to NISP instrument

1.2 m telescope at L2

VIS: single band 530-920nm

detector array: 36 4x4k pixels, Teledyne E2V

pixel scale: 0.1 arcsec -> FWHM=0.18 arcsec

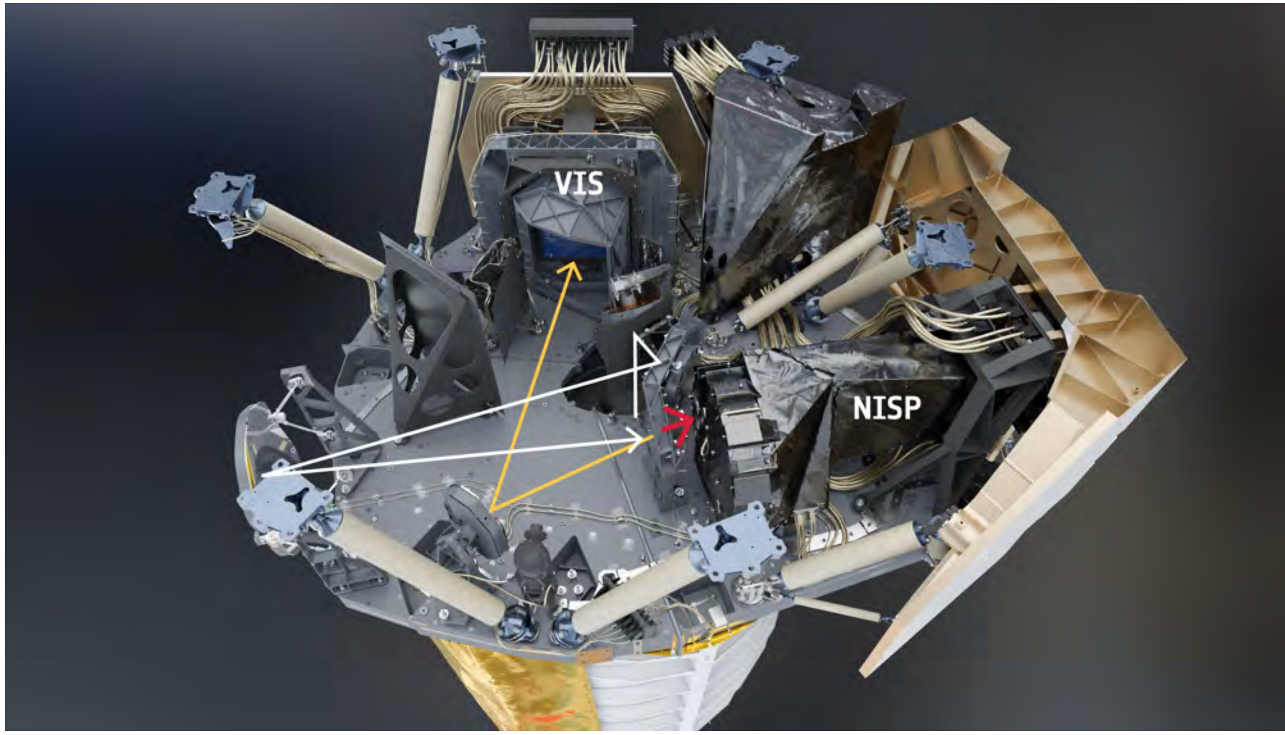
field of view: 0.57 deg^2

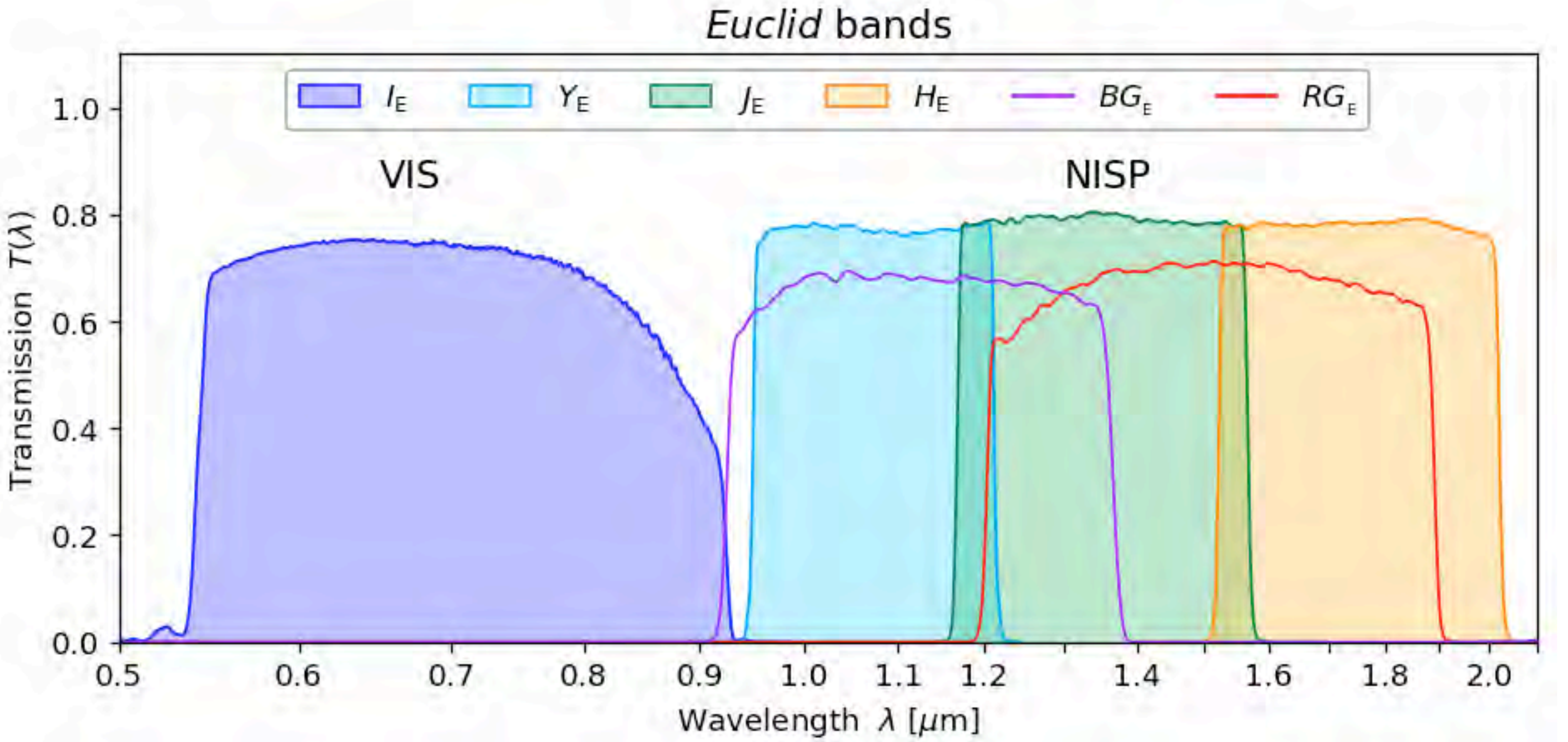
NISP: Y, J, H

detector array 16 2x2k H2RG

pixel scale: 0.3 arcsec, FWHM ~ 0.4 arcsec

field of view: 0.57 deg^2



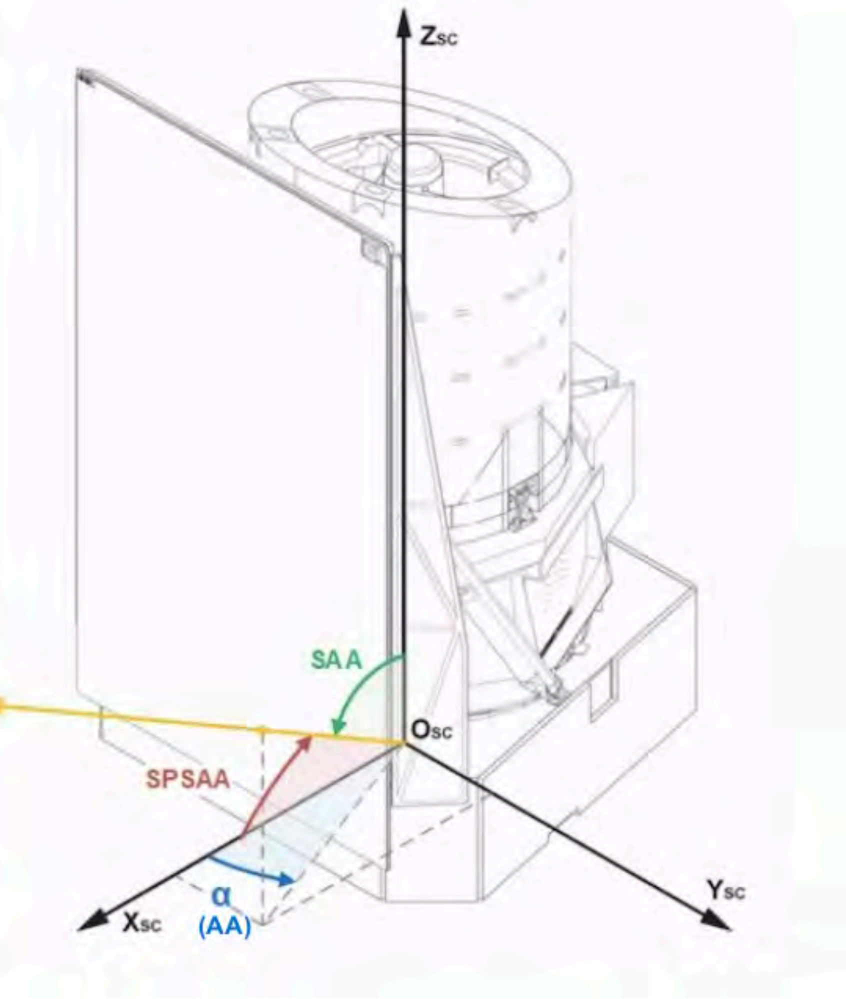


Euclid bands
I_E
Y_E
J_E
H_E
BG_E
RG_E
VIS
NISP
Transmission $T(\lambda)$
1.0
0.8
0.6
0.4
0.2
0.0
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.4
1.6
1.8
2.0
Wavelength λ [μm]

Since Euclid launch

4 issues :
FGS Guiding problem,
VIS straylight,
Xray Solar flares larger than expected (solar activity)
Throughput loss to icing (few %, need to decontaminate)

2 months lost due to FGS
Need to set a new range of pointing anglie to minimise light contamination:
from (-7.0º ≤ AA ≤ +7.0º) to (-8.5º ≤ AA ≤ -2.9º)



-> Create a non symmetric scan of the sky

Will need 6-12 months more

Survey will start mid-February 2024 !

Reference Observation Sequence (ROS)

4 dithers, each of them with :

- 285 s long VIS and 54 s short VIS
- 56 s for each of NISP YJH.
- NISP FWA would be set to the close position during VIS exposures.

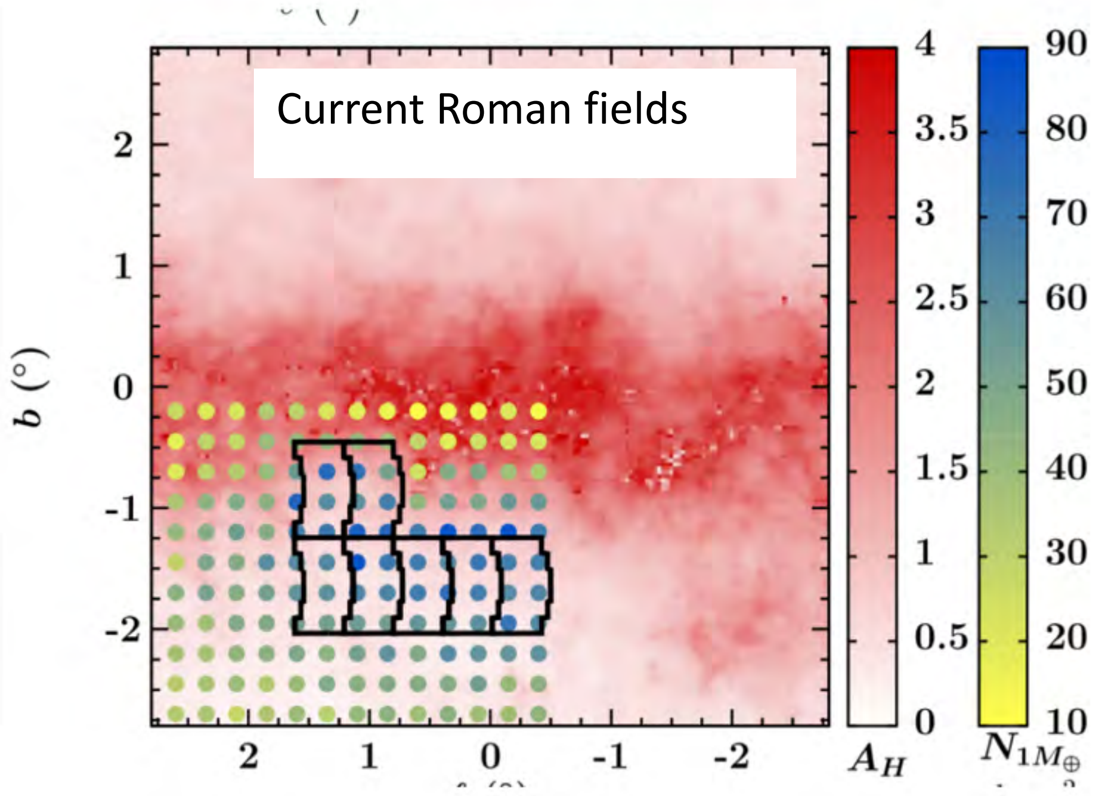
For the Euclid observations of Roman fields, we would do 4 x ROS at each dither to have enough S/N

Which field for Roman survey

Need to better understand which line of sight for the ~ 2 deg^2 of Roman

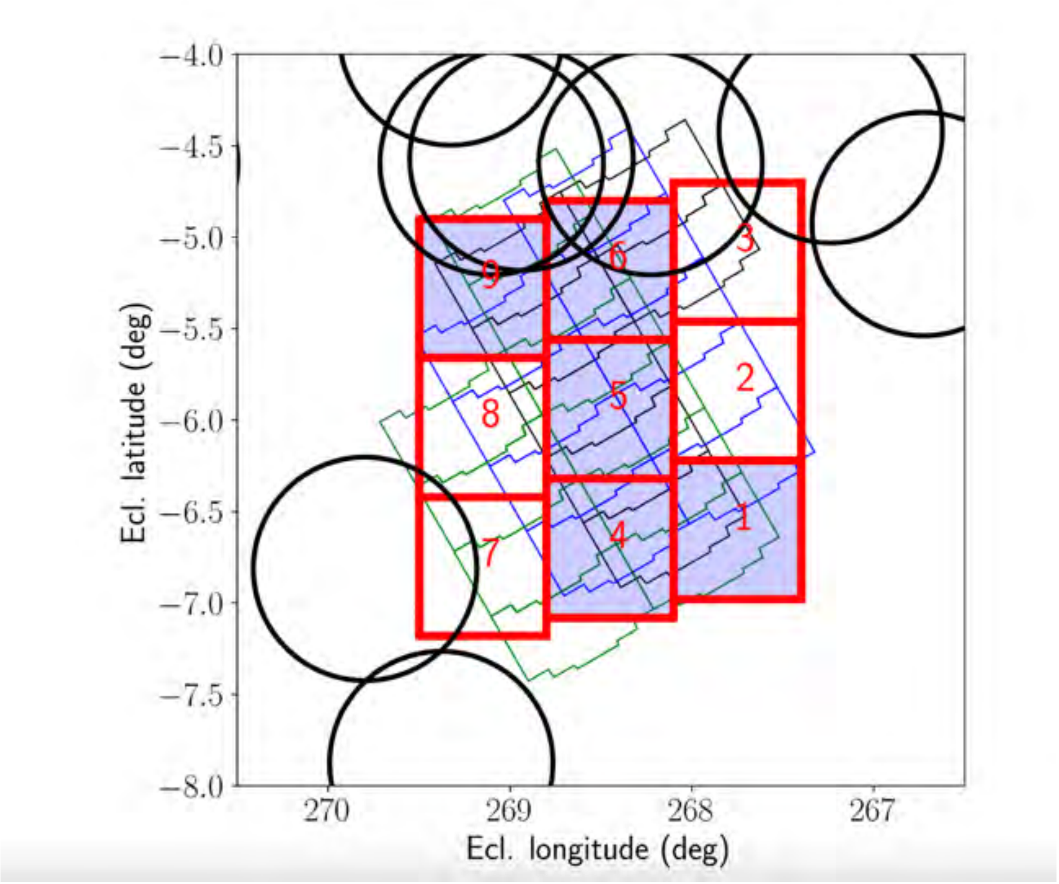
Trade off number of targets / possibility to well characterise them

Euclid (VIS, Y, J, H)



Colored dots give the detection yields of 1 $M_\oplus$ planet per deg^2

Proposed Euclid observations



Roman fields

Reference survey, 7 pointings

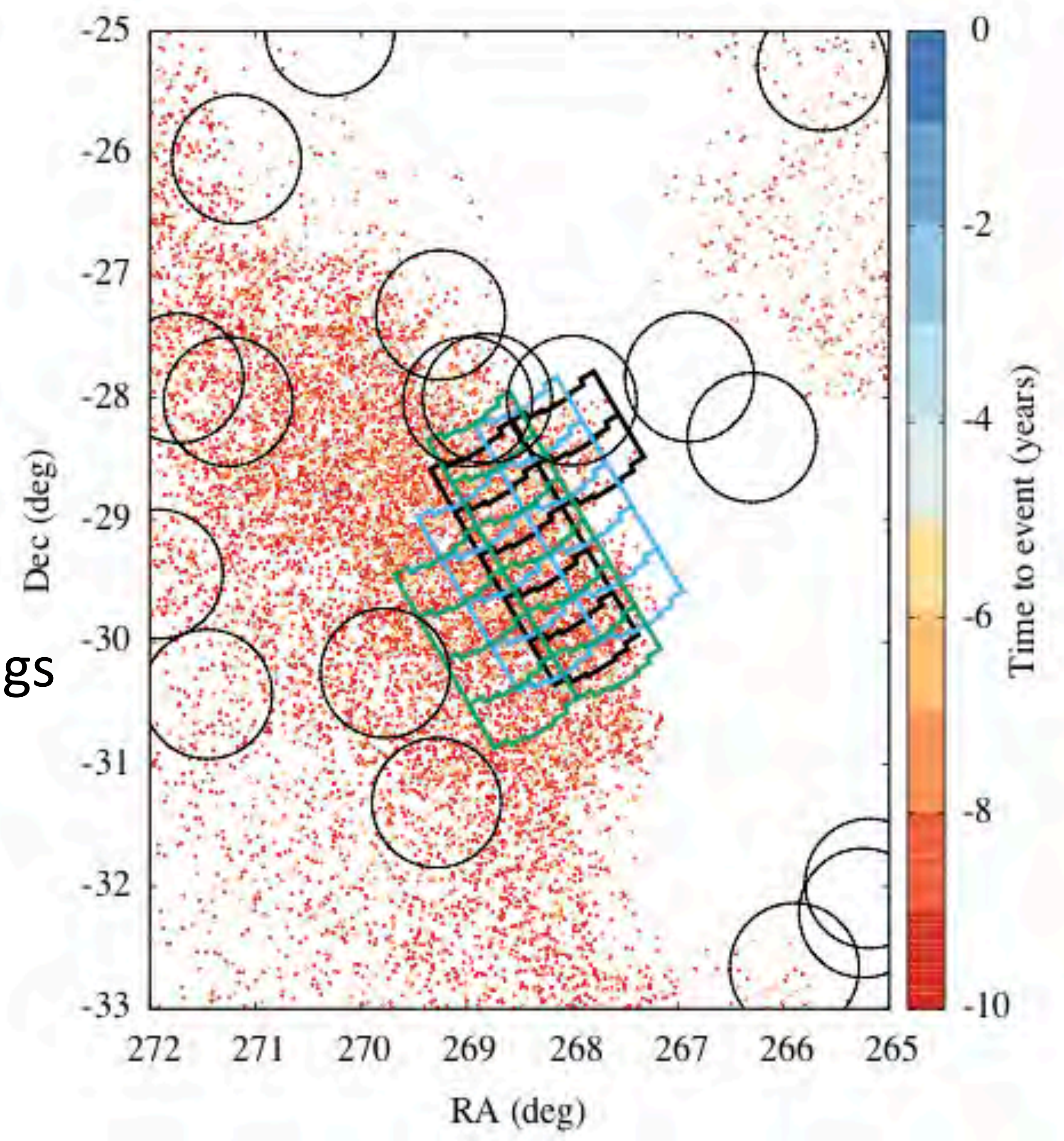
(in black, Penny et al. 2019)

Optimised survey, 9 pointings

(light blue)

Better for mass measuremets 10 pointings

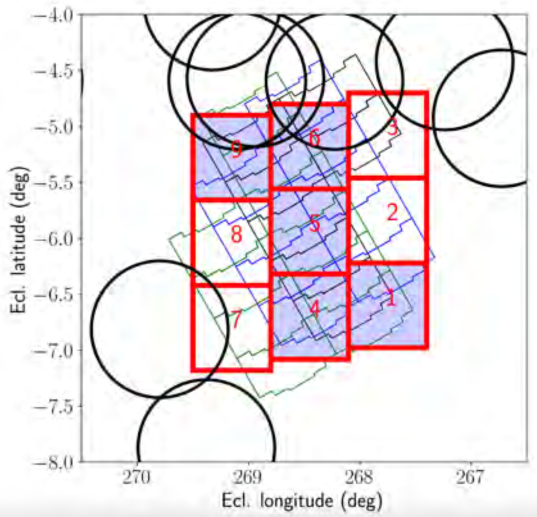
(in green)



9 Euclid pointings overlapping Roman

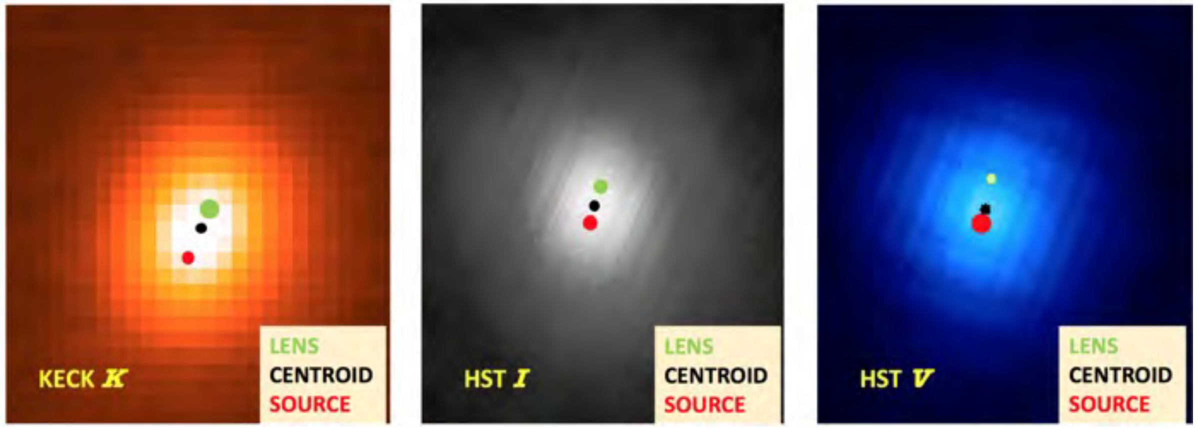
By surveying a 4.5 deg^2 region close to the Galactic Centre, 3-4 years before Roman is launched, Euclid can:

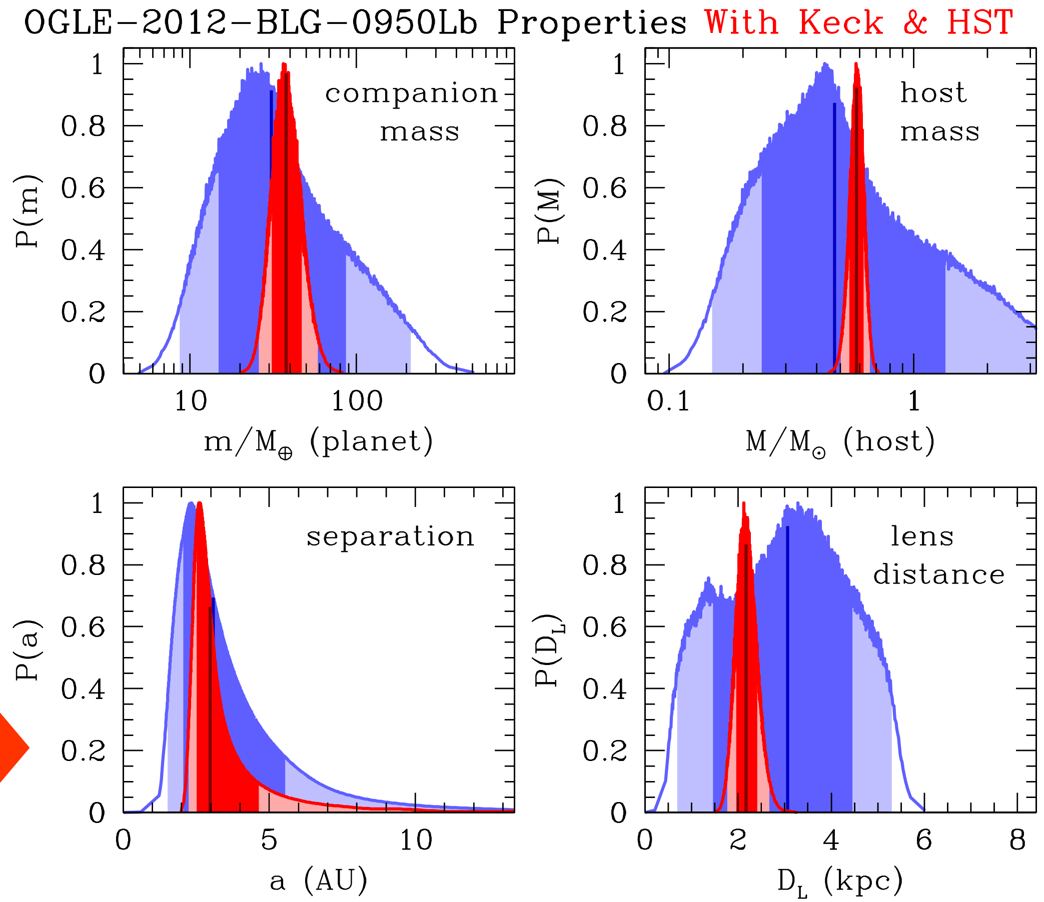
1) help to optimize the Roman field positions to optimise its exoplanet detection yield;
2) enable much more accurate (up to a factor 5-6) Roman exoplanet mass measurements by increasing the observation baseline for host star proper motion measurements;
3) enable the first Roman exoplanet mass measurements to be secured during the first year of the Roman survey.

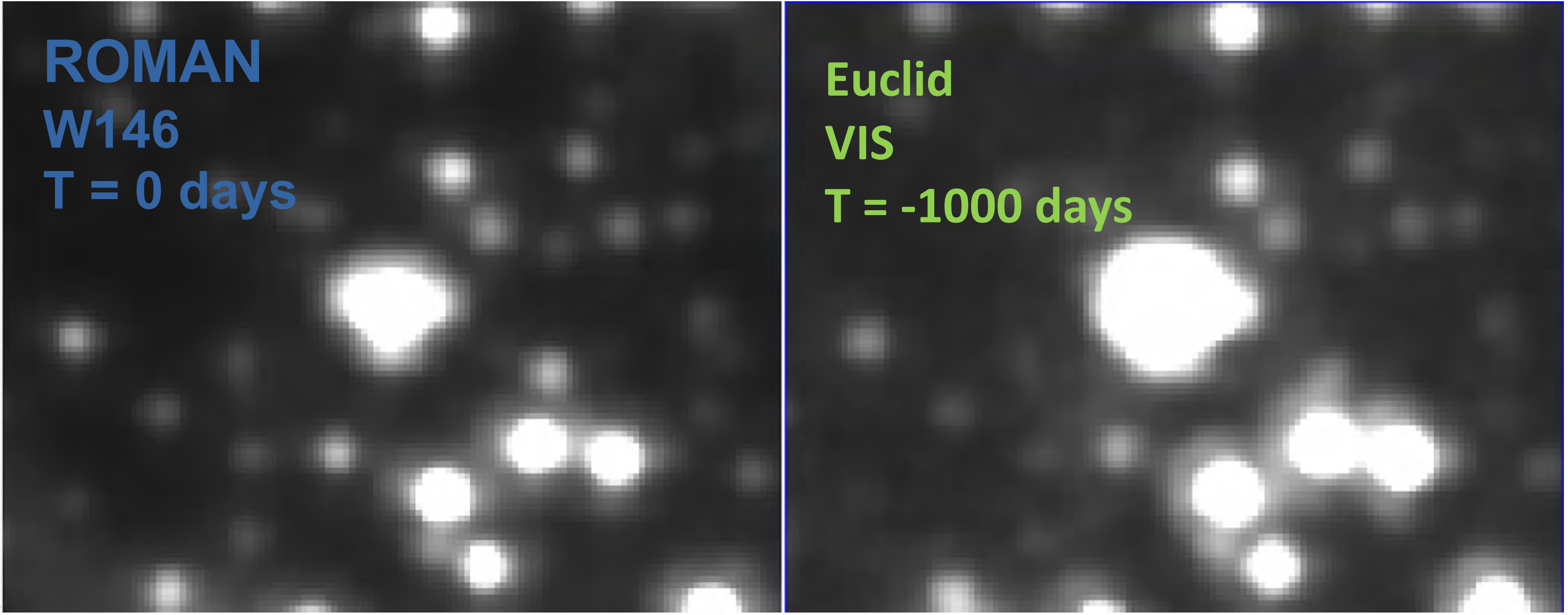


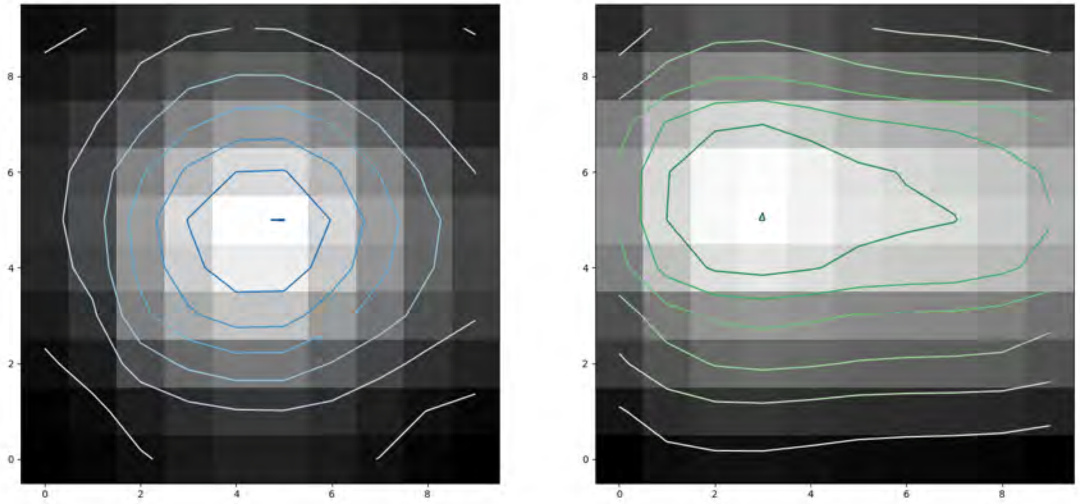
Resolving source/lens to measure masses to (~10 %)

Today, HST and KECK
RGES over 4-5 years with Roman to meet the requirements
Precursor Euclid observations and Roman to get masses from year-1
Euclid VIS









Precise mass measurement for planetary microlensing from year-1 of Roman

Courtesy Etienne Bachelet

At each pointing, a 16 dither approach

4 dithers, each of them with :

- 285 s long VIS and 54 s short VIS
- 56 s for each of NISP YJH.
- NISP FWA would be set to the close position during VIS exposures.

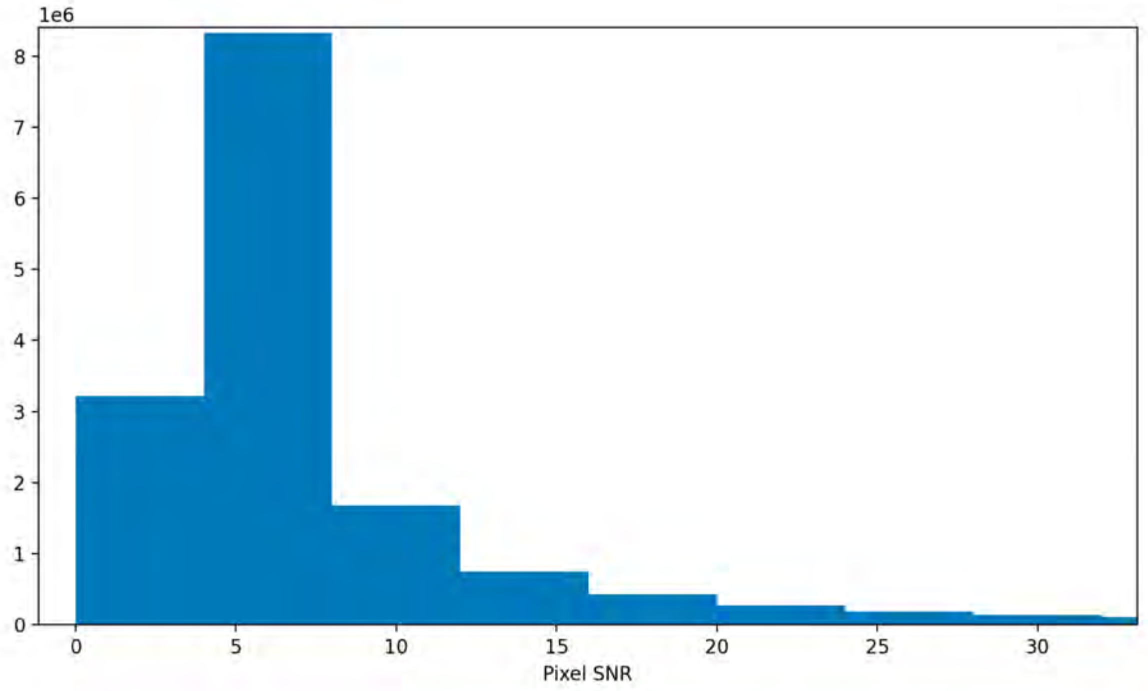


Figure 9: The distribution of pixel signal-to-noise ratio (SNR) of the Euclid VIS image constructed from a 16-dither pattern (used in Bachelet et al. 2022).

At each pointing, a 16 dither approach

Lens magnitude distributions seen by Roman (left) and Euclid (right). From Bachelet et al. 2002.

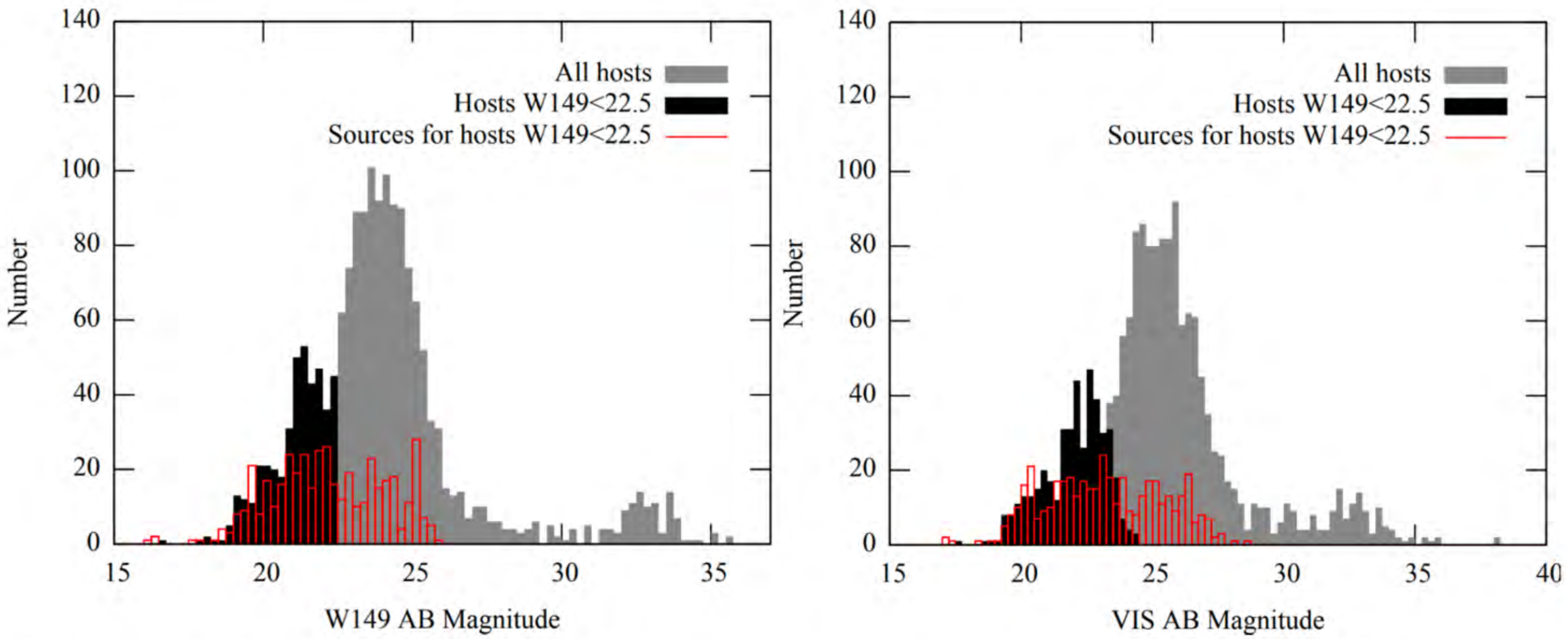


Figure 8: Simulated host lens magnitude distributions seen by Roman (left) and Euclid (right), assuming 16 dithered VIS observations of 300 sec duration (Bachelet et al. 2022). Black histograms show the magnitude distributions in Euclid VIS and Roman W146 passbands for hosts with W146 < 22.5 (making up about 25% of the entire simulated host population). These are well within range of Euclid VIS, with a zero point magnitude of 25.7.

Hunting for free-floating planets, planets on wide orbits

Parallax from simultaneous Euclid-Roman observations can constrain the masses of free-floaters

(Bachelet & Penny 2019, Bachelet et al. 2022)

Under consideration

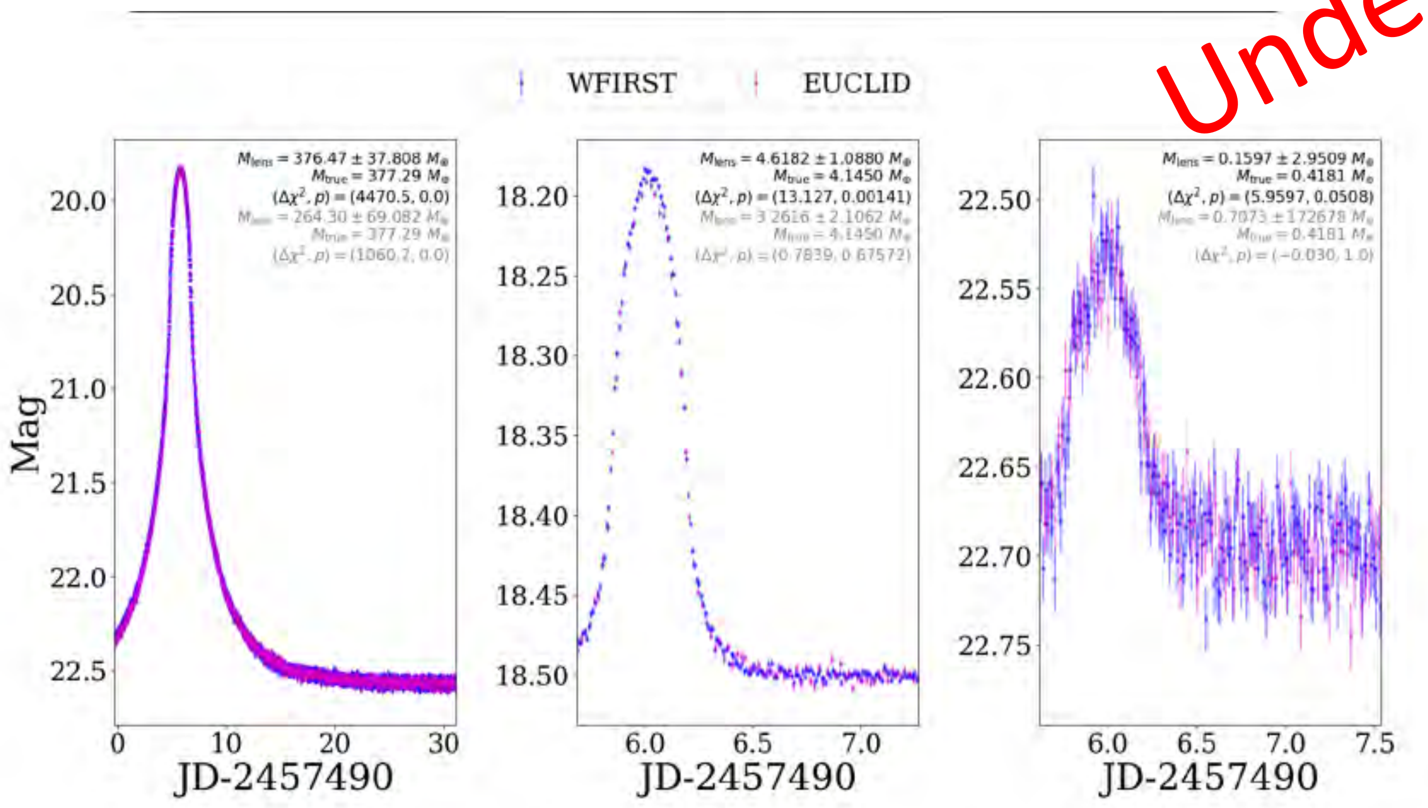


Fig. 1. Three simulated examples of microlensing events due to FFP lenses as seen by EUCLID and ROMAN. Best-fit parameters based only on ROMAN data are presented in gray in the top-right of each figure, while shown in black are best-fit solutions using both datasets. Note that the shifts in time and magnification due to the parallax are too small to be visible. Magnitudes are artificially aligned to the ROMAN system for the plotting.

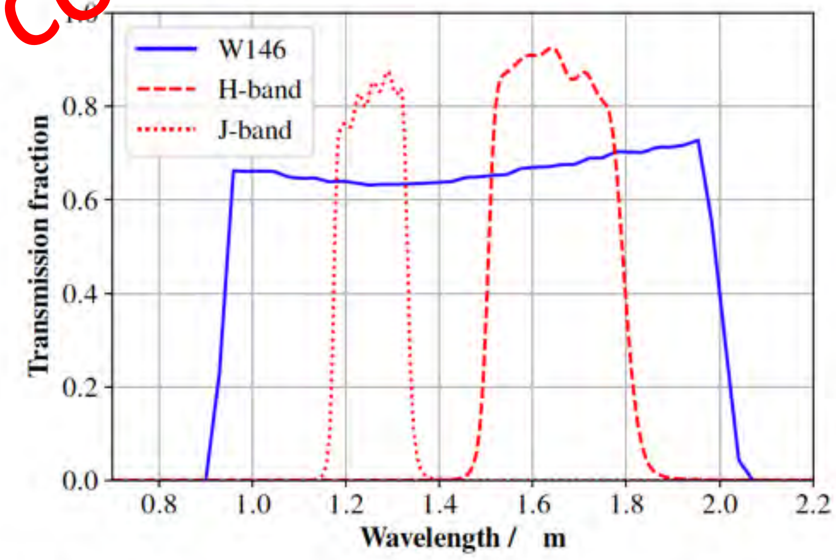


Fig. 2. The transmission curves for the ROMAN W146 and Johnson-Cousins J and H filters are shown. Data for the W146 transmission is available at: `https://wfirst.gsfc.nasa.gov/science/WFIRST_Reference_Information.html`

Summary

4.5 deg^2 survey of the Galactic bulge made up of 9 Euclid pointing, 42.5 hours for nominal survey

Learning about the Roman microlensing line of sight

Reference for source-lens proper motion of Roman planetary events, hence mass measurements from year-1 of Roman

Strong support of ESA, Euclid board and ROMAN PIT Exoplanet

Observations were planned for end of PV phase in oct 2023 (but FGS problems ☹)

Strongly supported by the Roman PIT exoplanet

On going discussion to implement it for october 2024

Potential simultaneous Euclid – Roman survey, 2028+

(to be officially proposed and discussed with Euclid)

Only way to measure masses of free-floating telluric planets via L2 parallax effects

Mass function of free-floating telluric planets down to 1 Earth mass

Selected references

- Penny M., et al., 2023**, "Euclid pre-cursor observations of the Roman Galactic Bulge Time Domain Survey region"**, for ESA/NASA
- Kerins E., et al. 2023, "**Magnifying NASA Roman GBTDS exoplanet science with coordinated observations by ESA Euclid »,** arXiv:2306.10210
- Bachelet E. et al., 2022, **"Euclid-Roman joint microlensing survey: Early mass measurement, free floating planets, and exomoons"**, Astronomy and Astrophysics 664, 136
- Bachelet E. & Penny M., 2019, "**WFIRST and EUCLID: Enabling the Microlensing Parallax Measurement from Space »,** Astrophysical Journal Letters, Volume 880, Issue 2, L32
- Vandourou E. et al., 2020, **"Revisiting MOA 2013-BLG-220L: A Solar-type Star with a Cold Super-Jupiter Companion"**, Astronomical Journal 160, 121
- Penny M. et al. 2013, « **ExELS: an exoplanet legacy science proposal for the ESA Euclid mission - I. Cold exoplanets »,** Monthly Notices of the Royal Astronomical Society, Volume 434, Issue 1,