Supercharging Roman exoplanet demography through a precursor survey with ESA Euclid

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Euclid 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

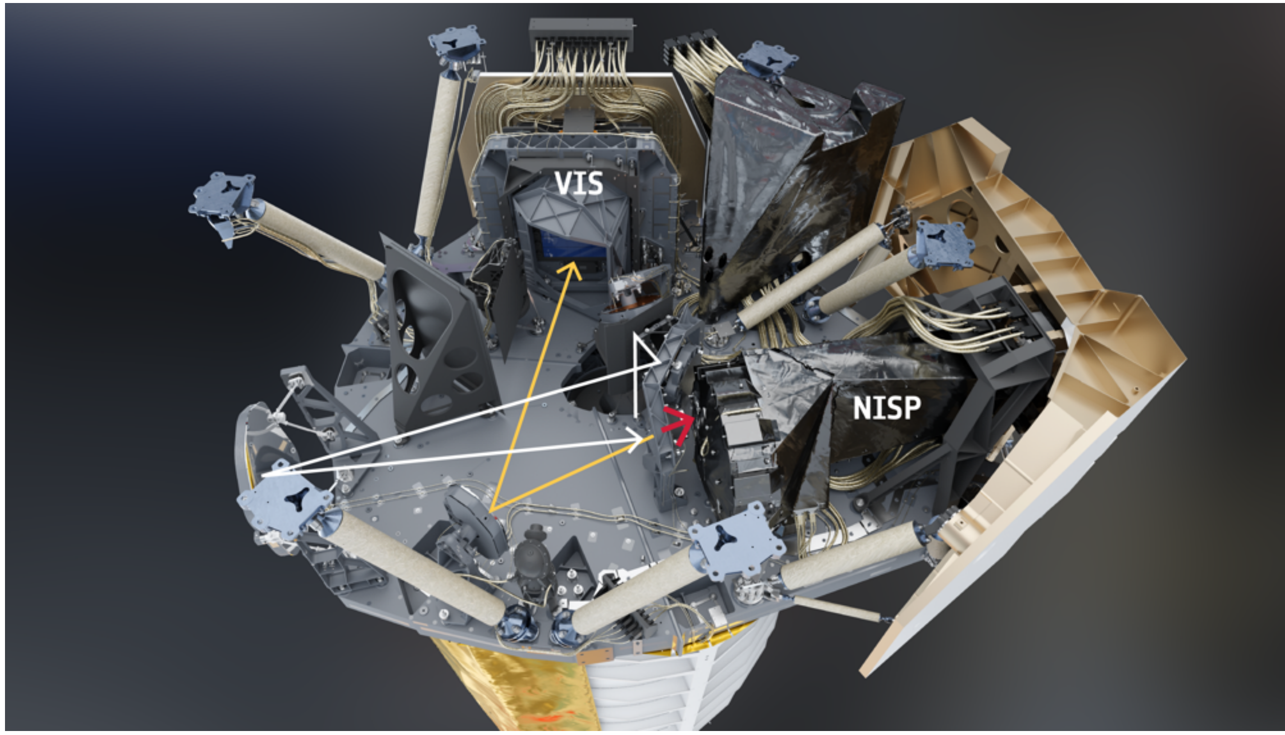
field of view: 0.57 deg^2

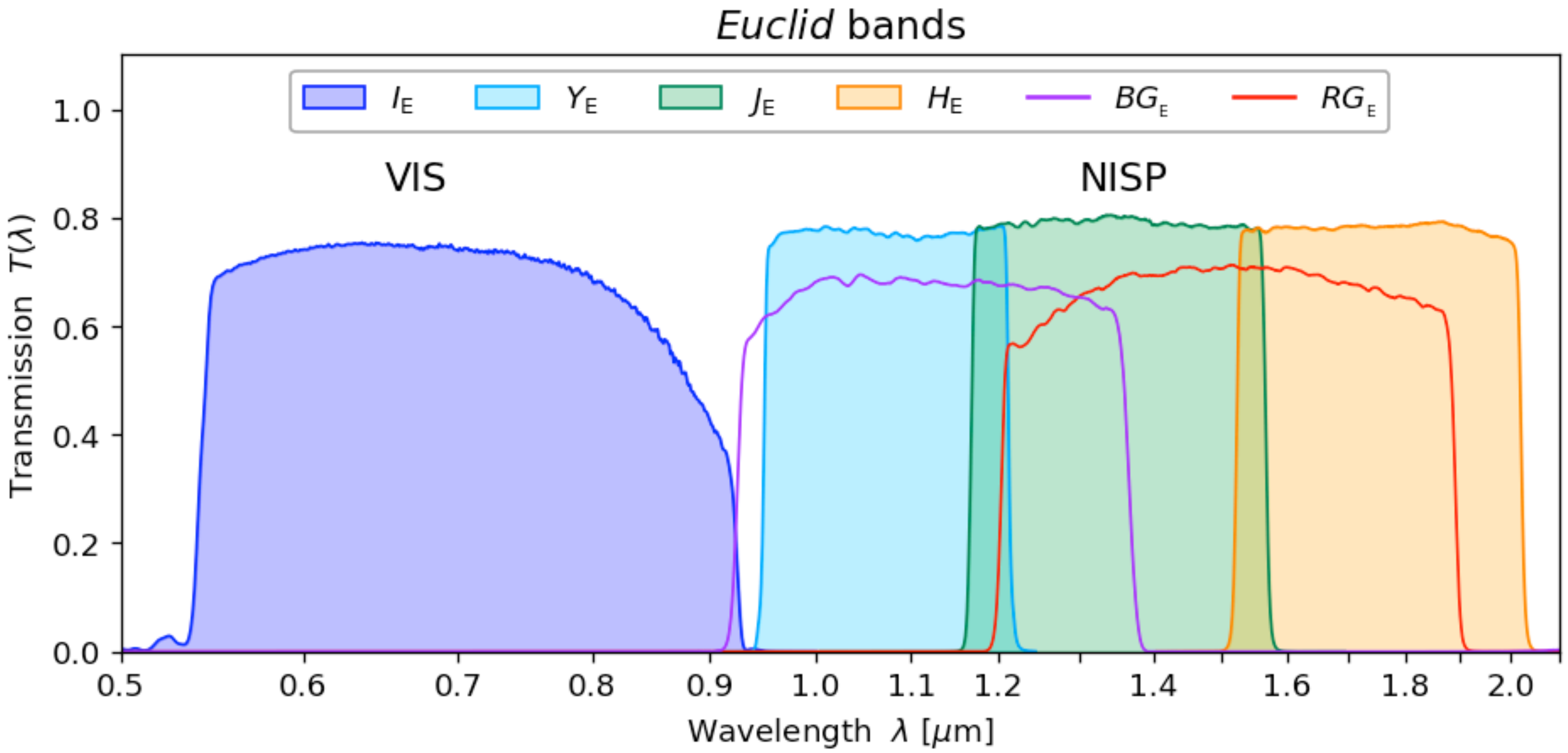
NISP: Y, J, H

detector array 16 2x2k H2RG

pixel scale: 0.3 arcsec, FWHM ~ 0.4 arcsec

field of view: 0.57 deg^2



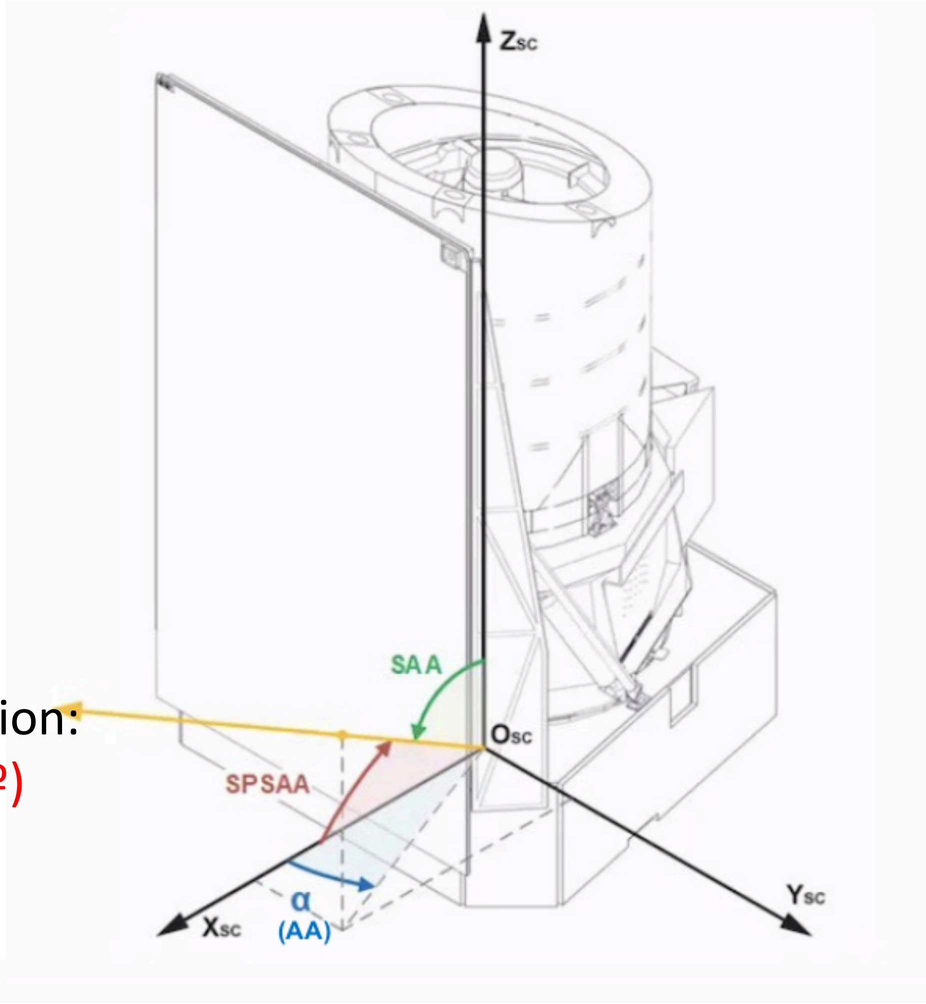


Euclid bands
I_E
Y_E
J_E
H_E
BG_E
RG_E
VIS
NISP
Transmission $T(\lambda)$
Wavelength λ [μm]
0.0
0.2
0.4
0.6
0.8
1.0
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.4
1.6
1.8
2.0

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 to perform the survey

Survey on going.

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

Roman fields

Reference survey, 7 pointings

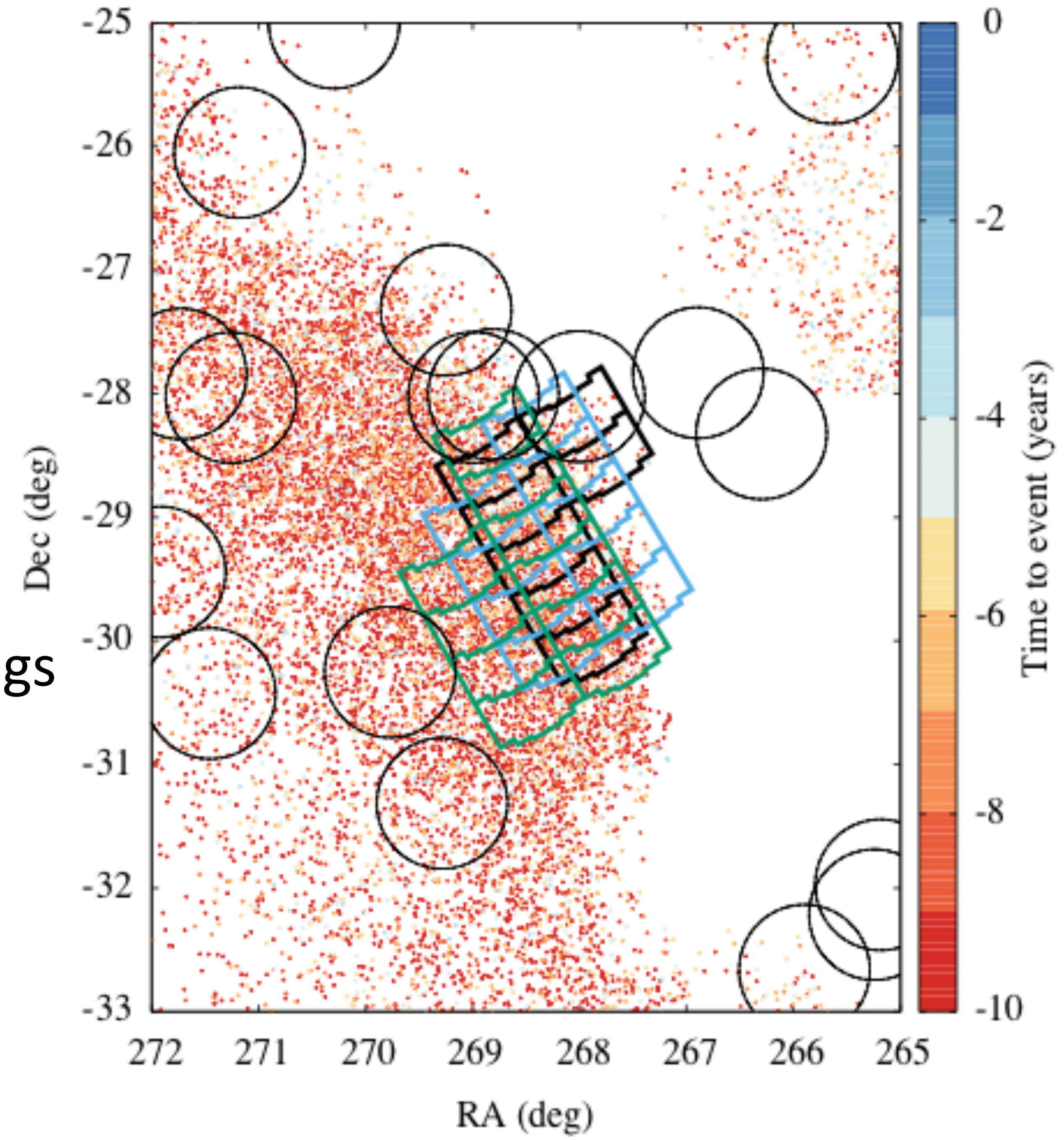
(in black, Penny et al. 2019)

Optimised survey, 9 pointings

(light blue)

Better for mass measuremets 10 pointings

(in green)

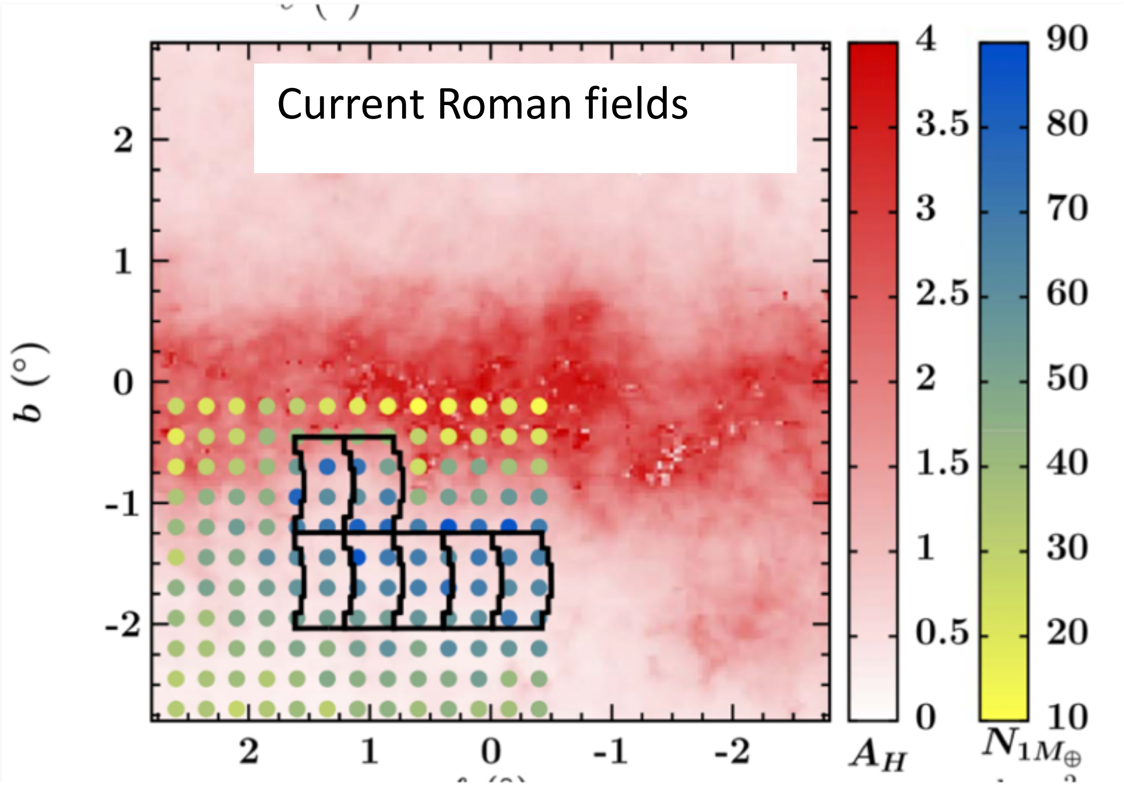


Which field for Roman survey

Need to better understand which line of sight for the ~ 2 deg² of Roman

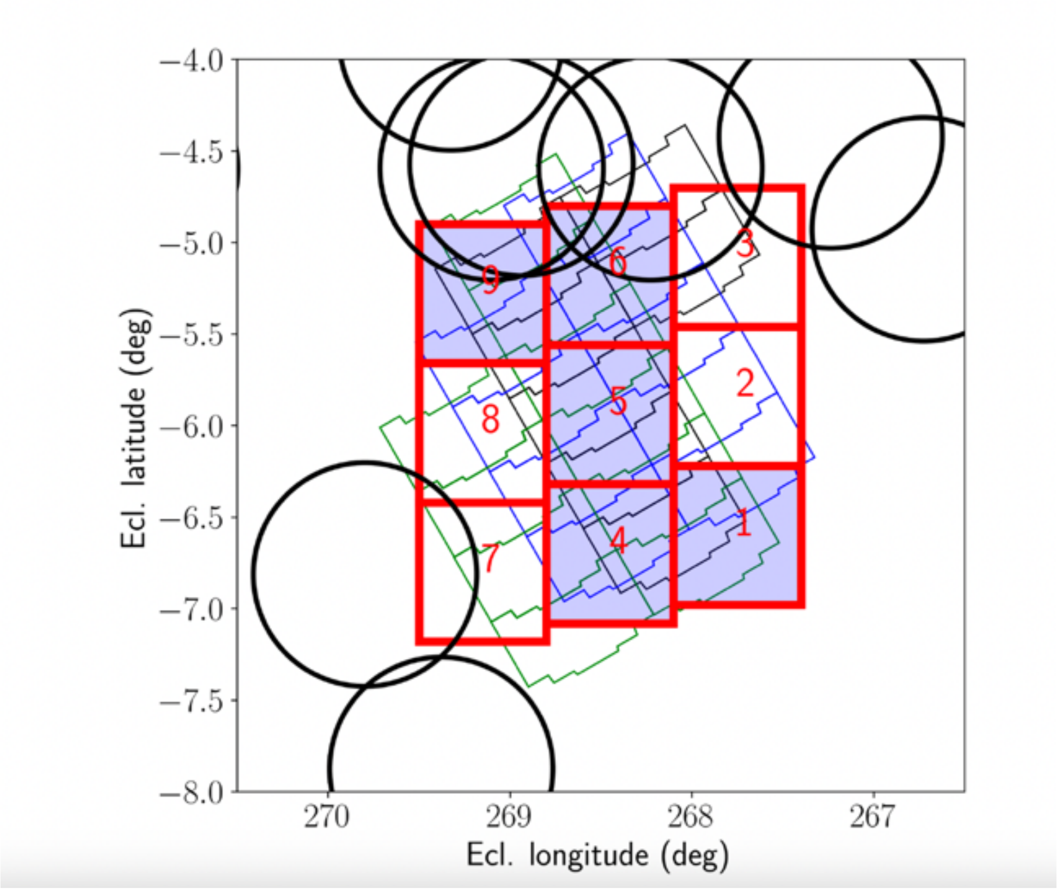
Trade off number of targets / possibility to well characterise them

Euclid (VIS, Y, J, H)



Colored dots give the detection yields of 1 $M_\oplus$ planet per deg²

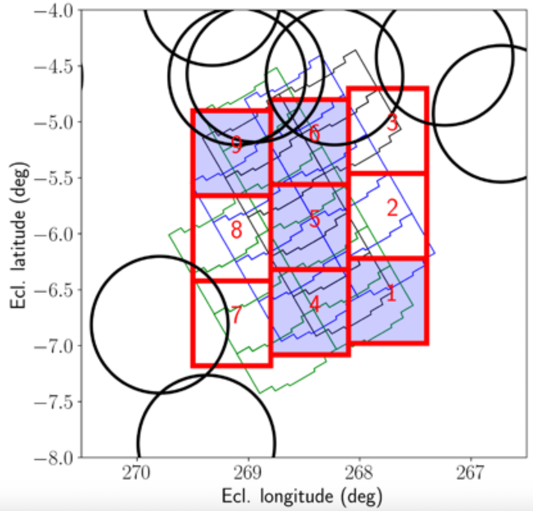
Proposed Euclid observations



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.



At each pointing, 4 x standard Reference Observing Sequence.

4 ROS, 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.

4ROS means 16 dither at each position.
~ 43 hours for 9 fields.

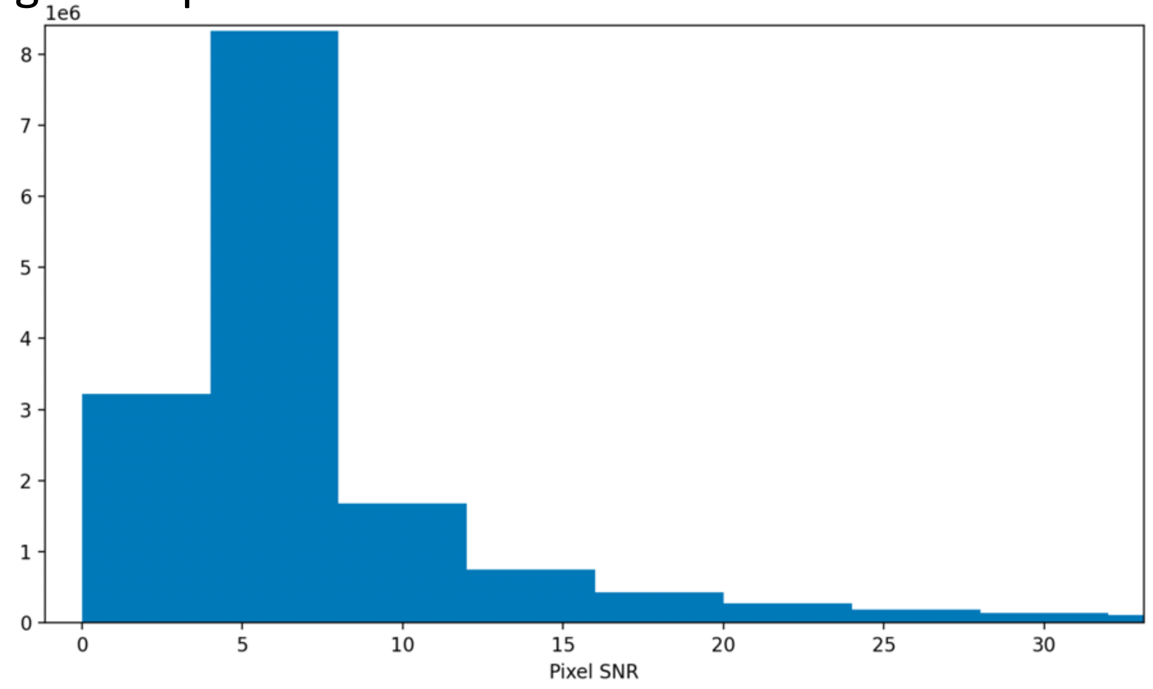


Figure 9: The distribution of pixel signal-to-noise ratio (SNR) of the Euclid VIS image constructed from a 16-dither pattern (used in Bachelet et al. 2022).

At each pointing, a 16 dither approach

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

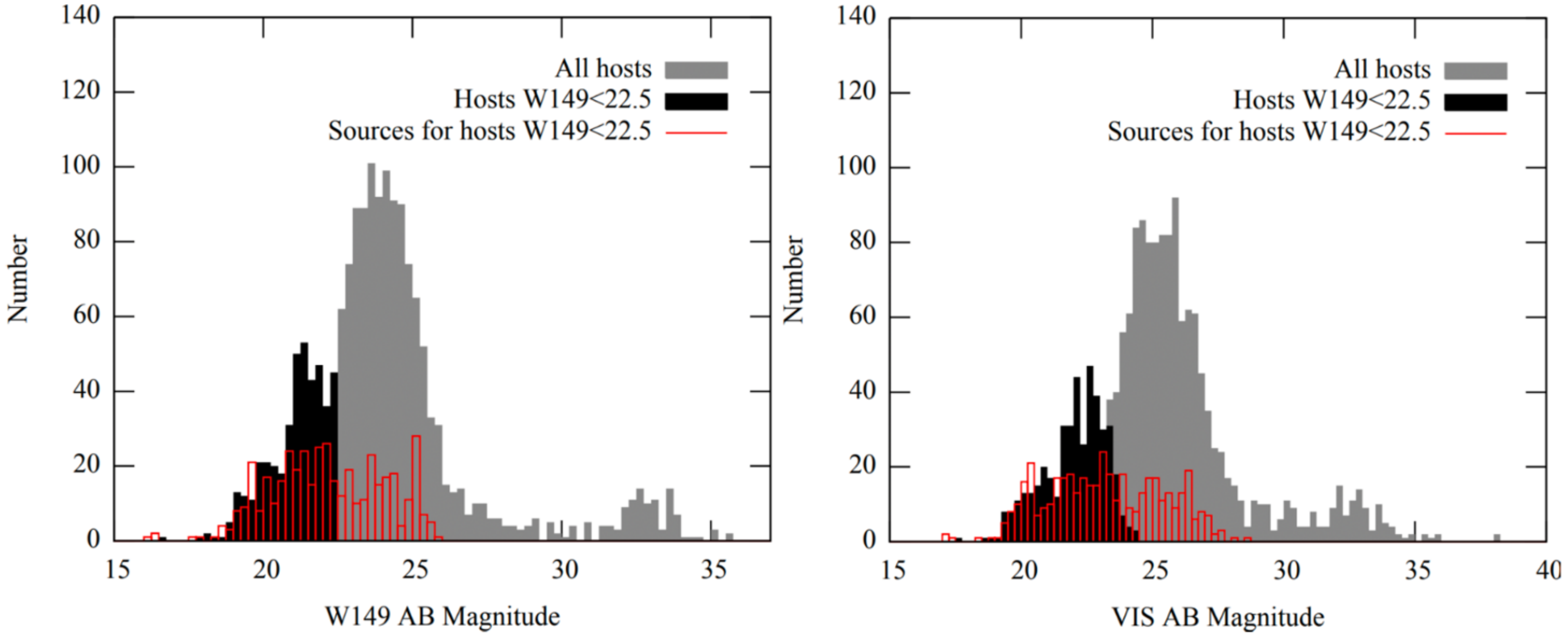
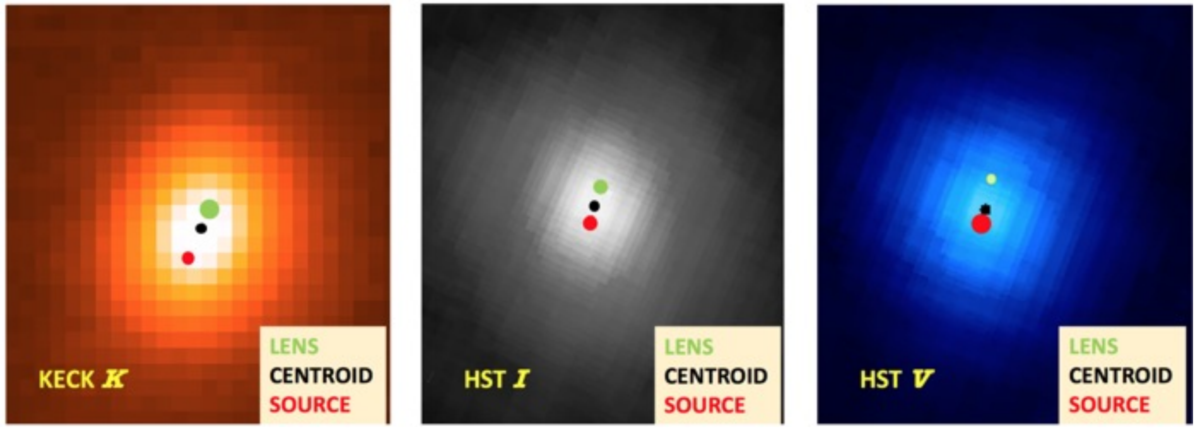
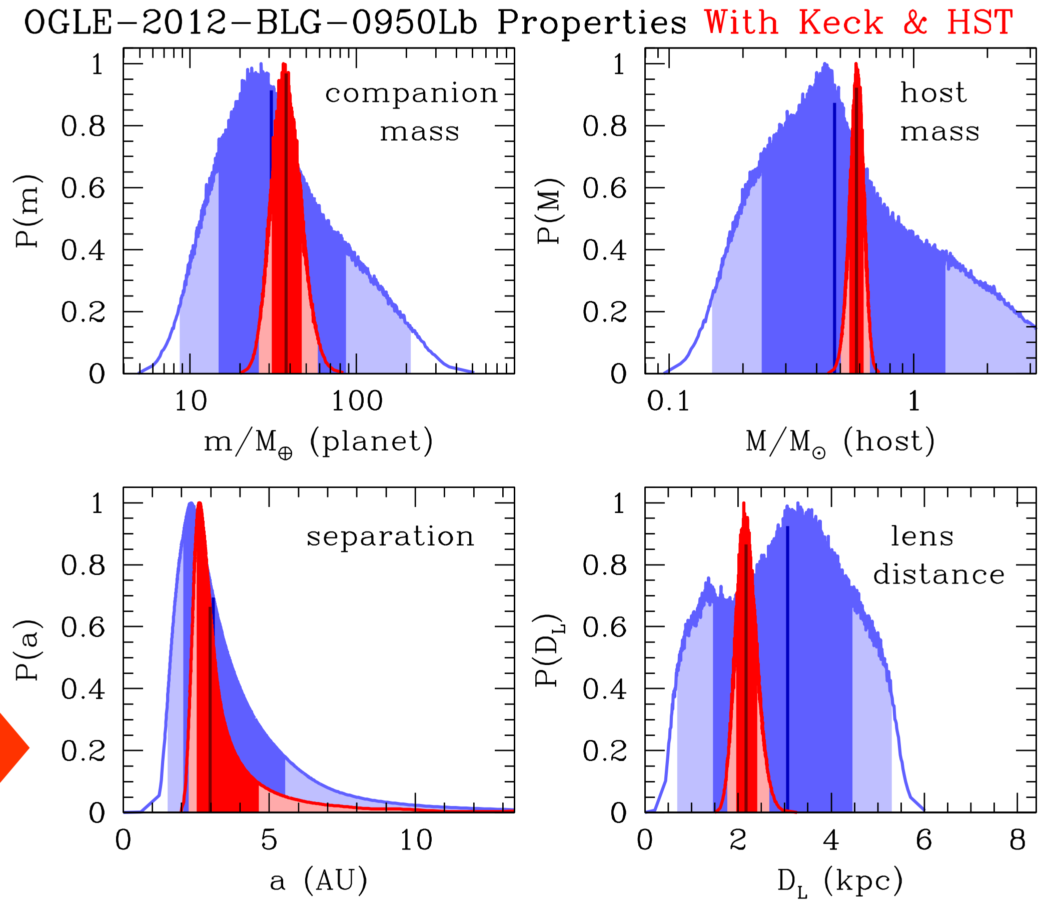


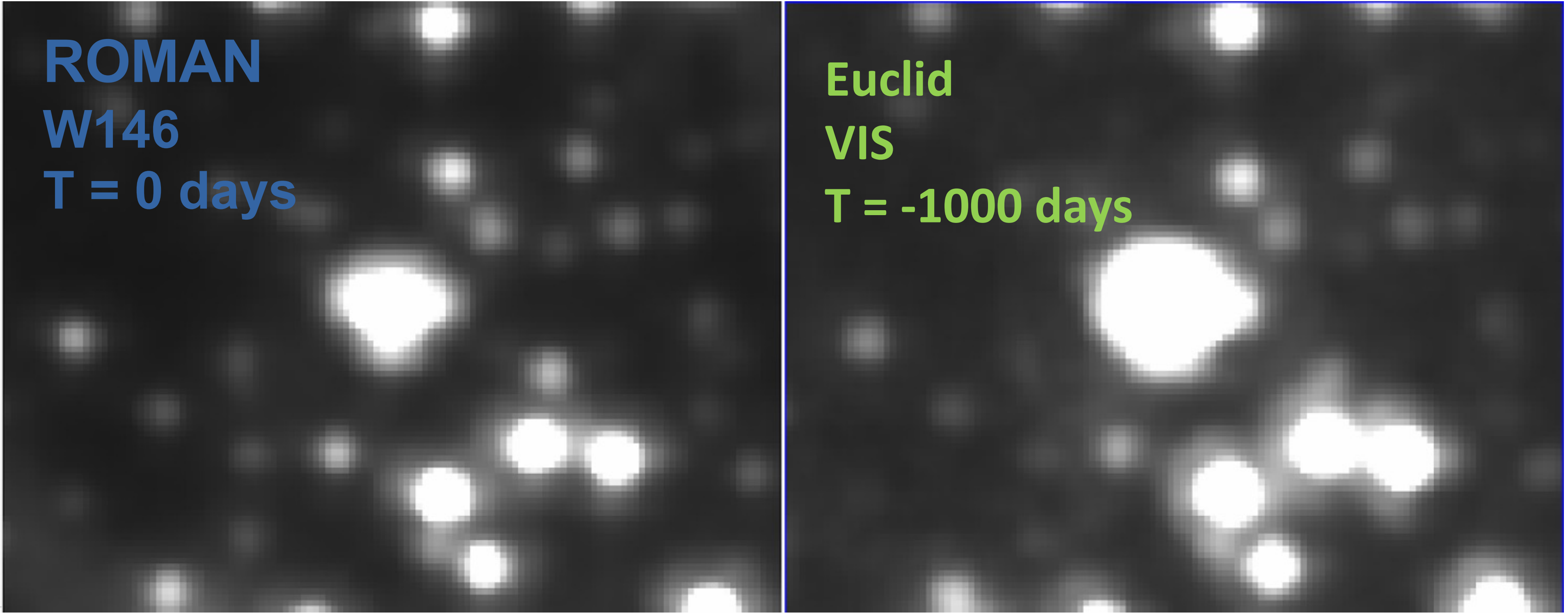
Figure 8: Simulated host lens magnitude distributions seen by Roman (left) and Euclid (right), assuming 16 dithered VIS observations of 300 sec duration (Bachelet et al. 2022). Black histograms show the magnitude distributions in Euclid VIS and Roman W146 passbands for hosts with W146 < 22.5 (making 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.

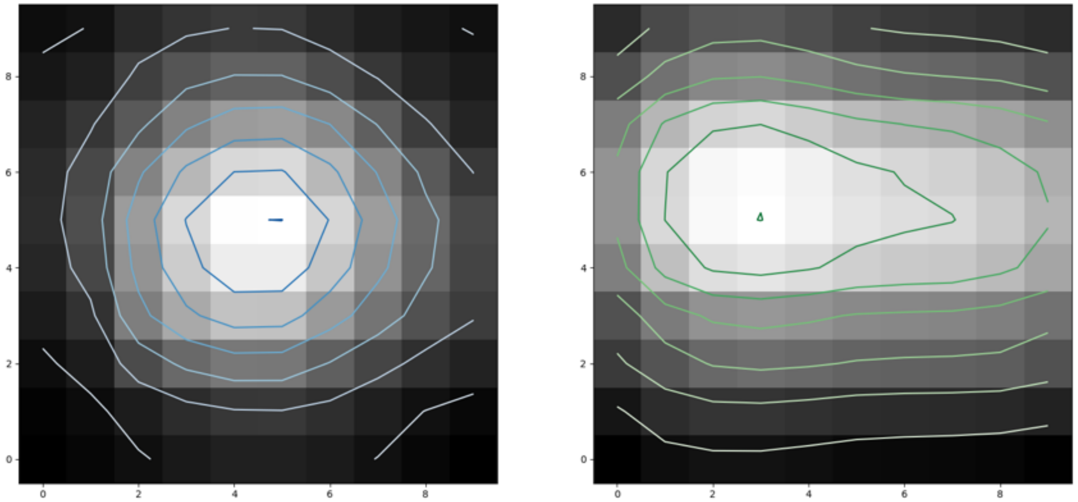
Resolving source/lens to measure masses to (~10 %)

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

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

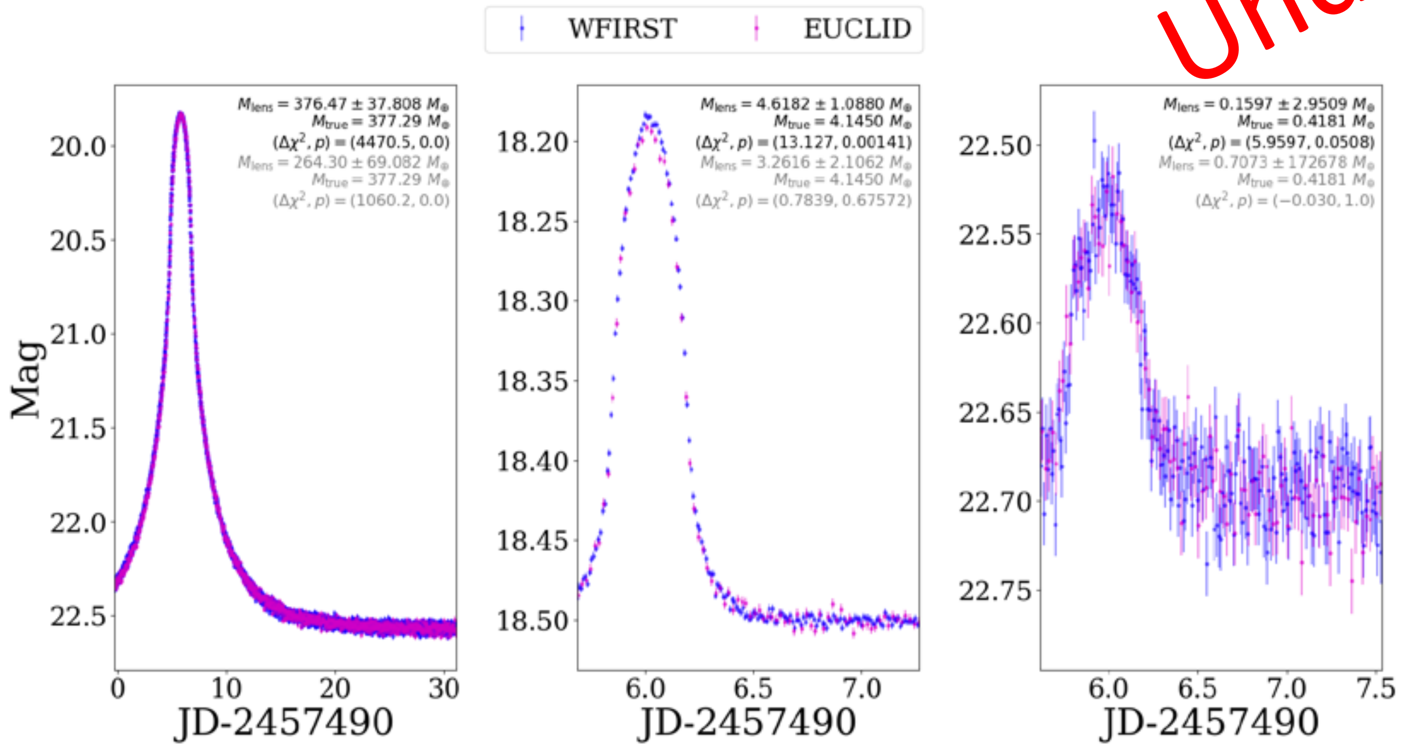


Fig. 1. Three simulated examples of microlensing events due to FFP lenses as seen by EUCLID and ROMAN. Best-fit parameters based only on ROMAN data are presented in gray in the top-right of each figure, while shown in black are best-fit solutions using both datasets. Note that the shifts in time and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

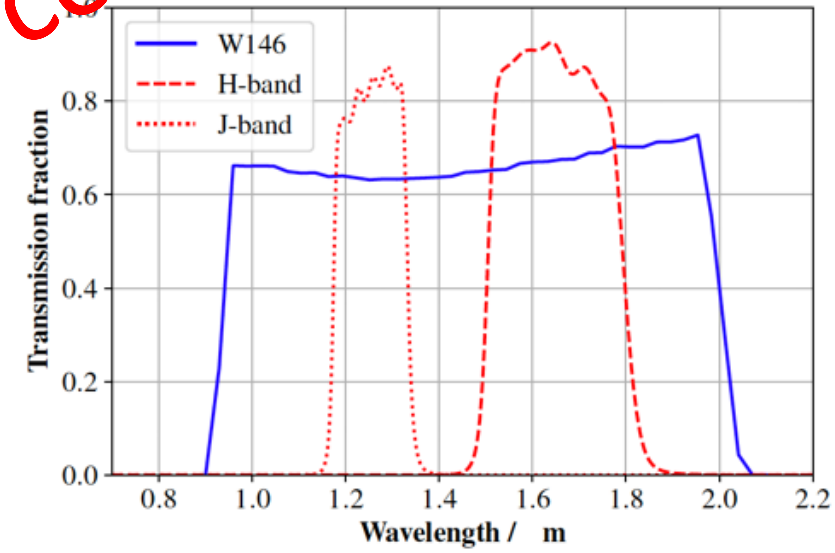


Fig. 2. The transmission curves for the ROMAN W146 and Johnson-Cousins J and H filters are shown. Data for the W146 transmission is available at: `https://wfirst.gsfc.nasa.gov/science/WFIRST_Reference_Information.html`

Summary

4.5 deg^2 survey of the Galactic bulge made up of 9 Euclid pointing, 43 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 ☹)

Likely done in March 2025

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 and below

Flares mimicking of free-floating planets can be excluded because there will be no parallax signal between Euclid and Roman.

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
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- 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,