

Status Report of “Extended Wide Imaging with Subaru HSC of the Euclid Sky (WISHES+)”

Subaru Intensive Program starting from S24B

Ken Osato (Chiba U) on behalf of WISHES+ team

2025/01/30; Subaru Users Meeting FY2024

1. WISHES+ Science with Euclid

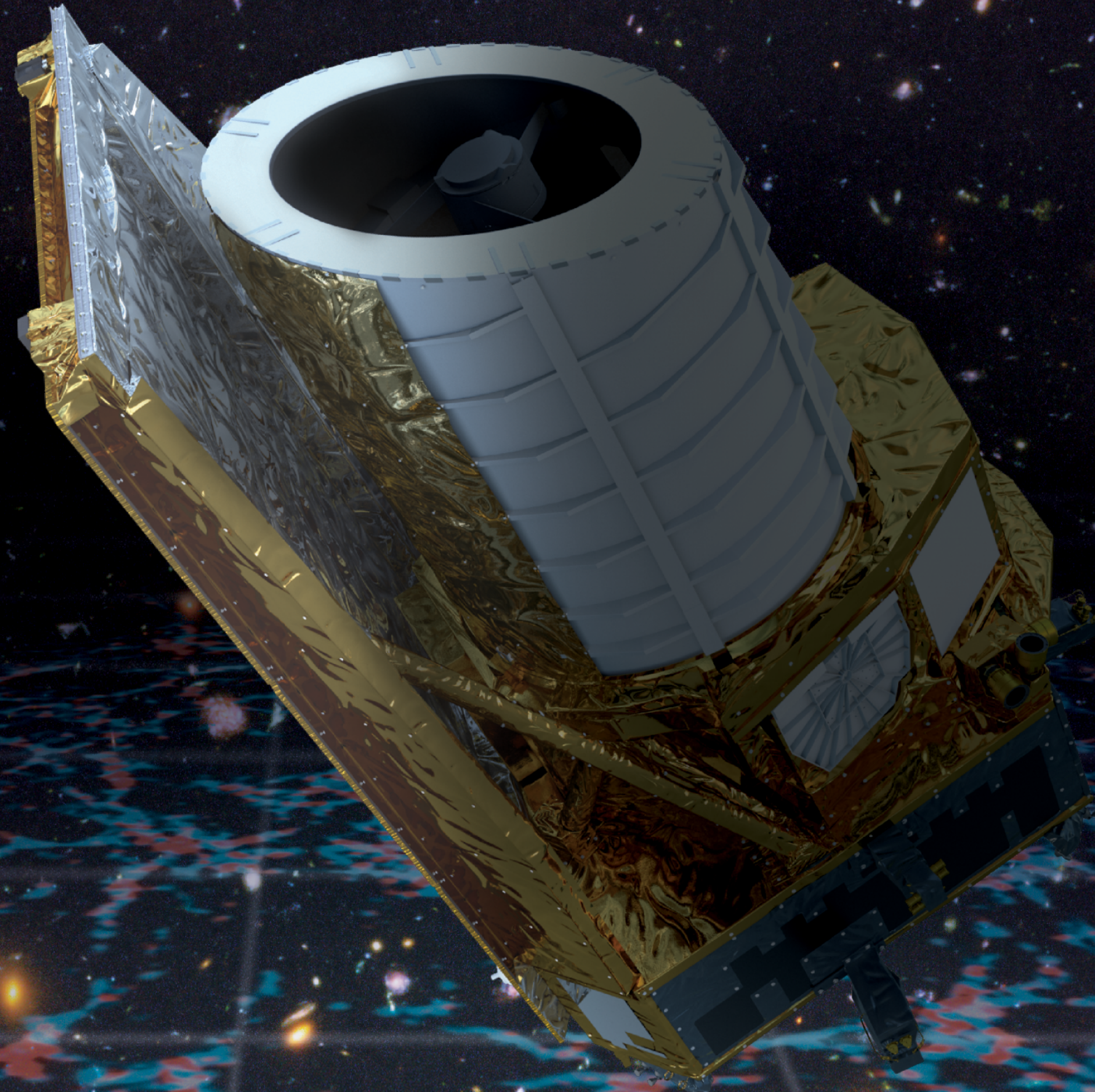
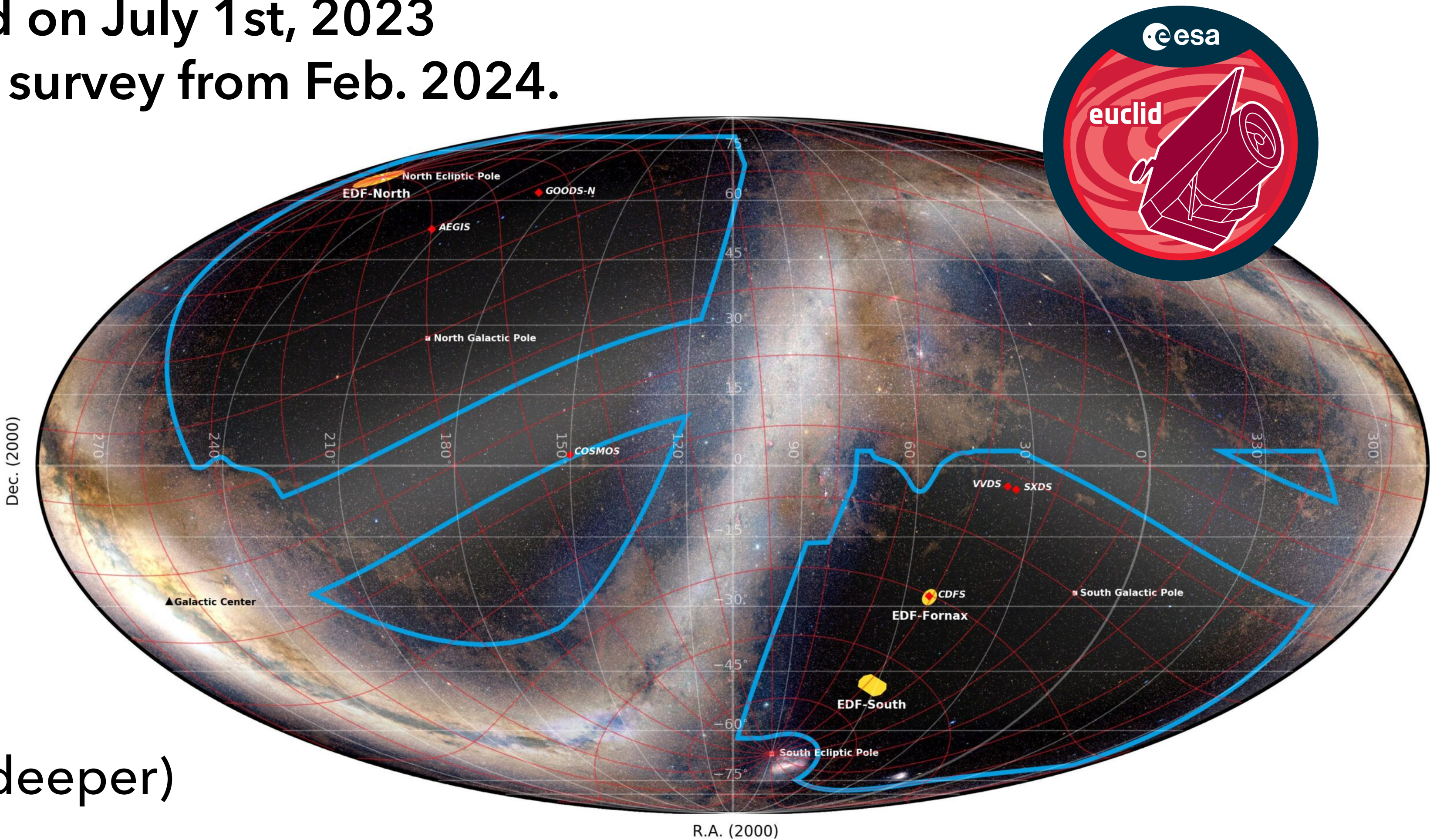


Image credit: ESA

Euclid Survey

◆ Euclid satellite was launched on July 1st, 2023 and began 6-year wide field survey from Feb. 2024.

- **Wide Imaging Survey**
(14,000 deg², VIS+NIR)
Core science: *Weak lensing*
- **Wide Spec. Survey**
(14,000 deg², grism)
Core science: *Galaxy clustering*
- **Deep Survey**
(3 patches, 53 deg², 2 mag deeper)



The 15,000 deg.² Euclid Wide Survey, the 53 deg.² Euclid Deep Survey, and the 6 deep auxiliary fields (6.5 deg.²) [Mollweide Celestial]

- ▭ Euclid Wide Survey region of interest : 16 Kdeg.² compliant with a 15 Kdeg.² survey
- ▭ Euclid Deep Fields : North=20 deg.², Fornax=10 deg.², South=23 deg.²
- ◆ Euclid deep auxiliary fields (GOODSN=0.5, AEGIS=1, COSMOS=2, VVDS=0.5, SXDX=2, CDFS=0.5 deg.²)



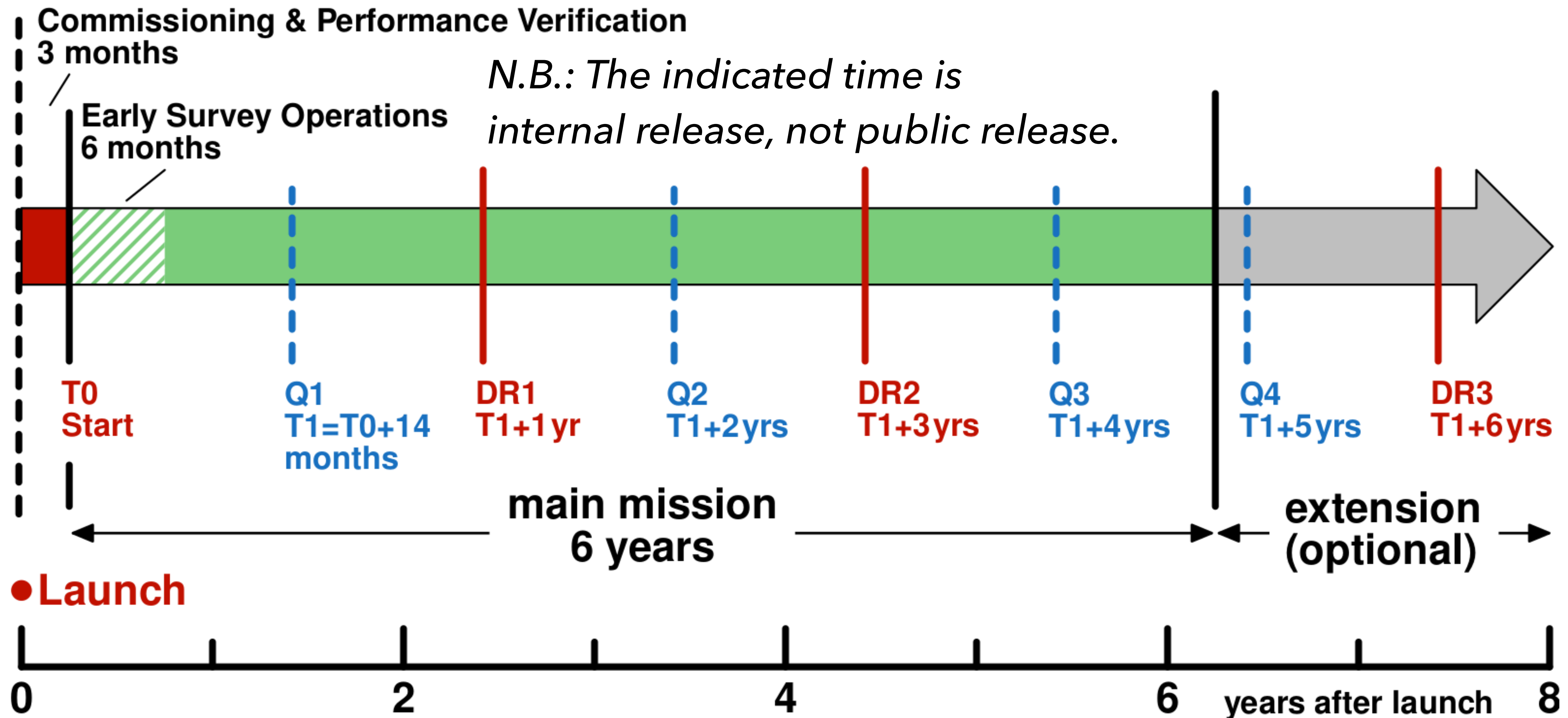
Background image: Euclid Consortium / Planck Collaboration / A. Mellinger



Image credit: ESA

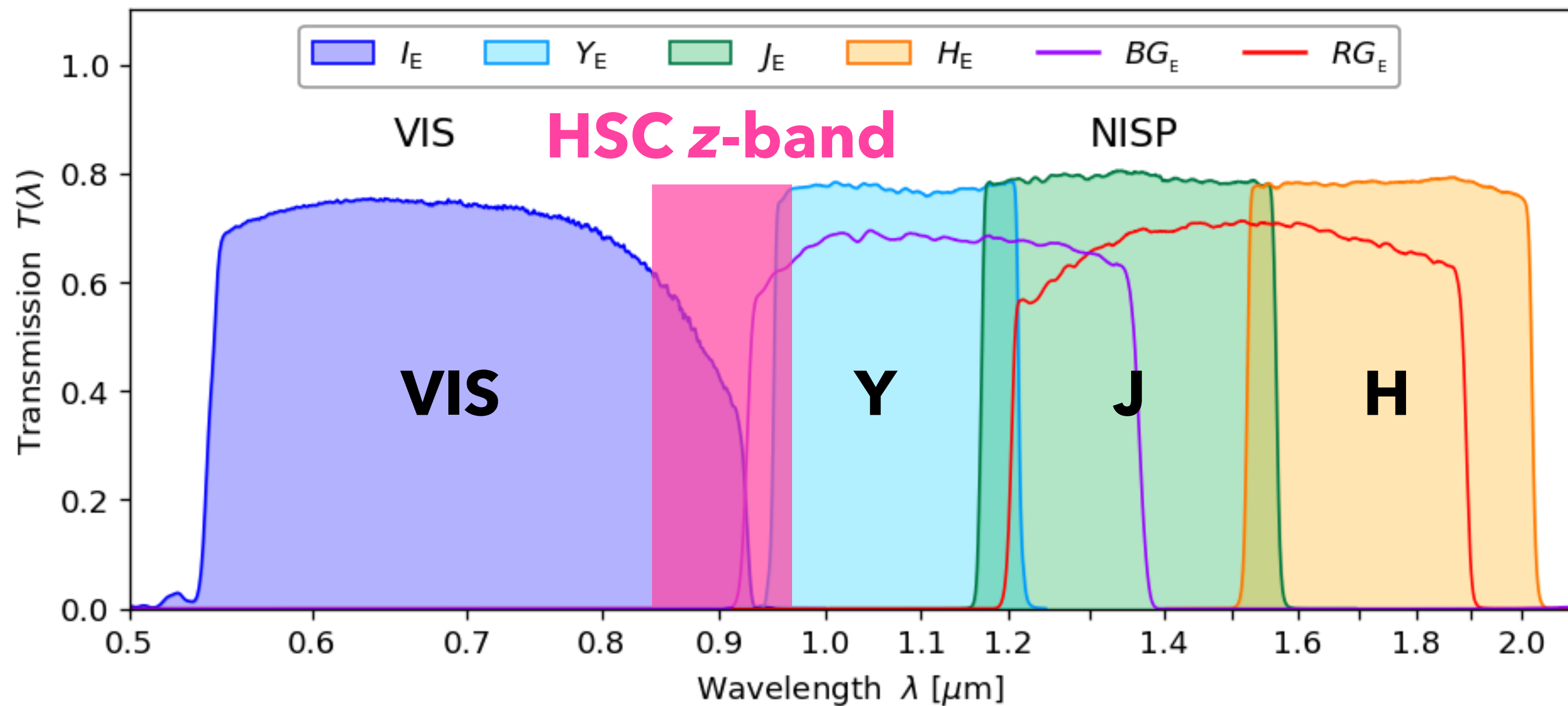
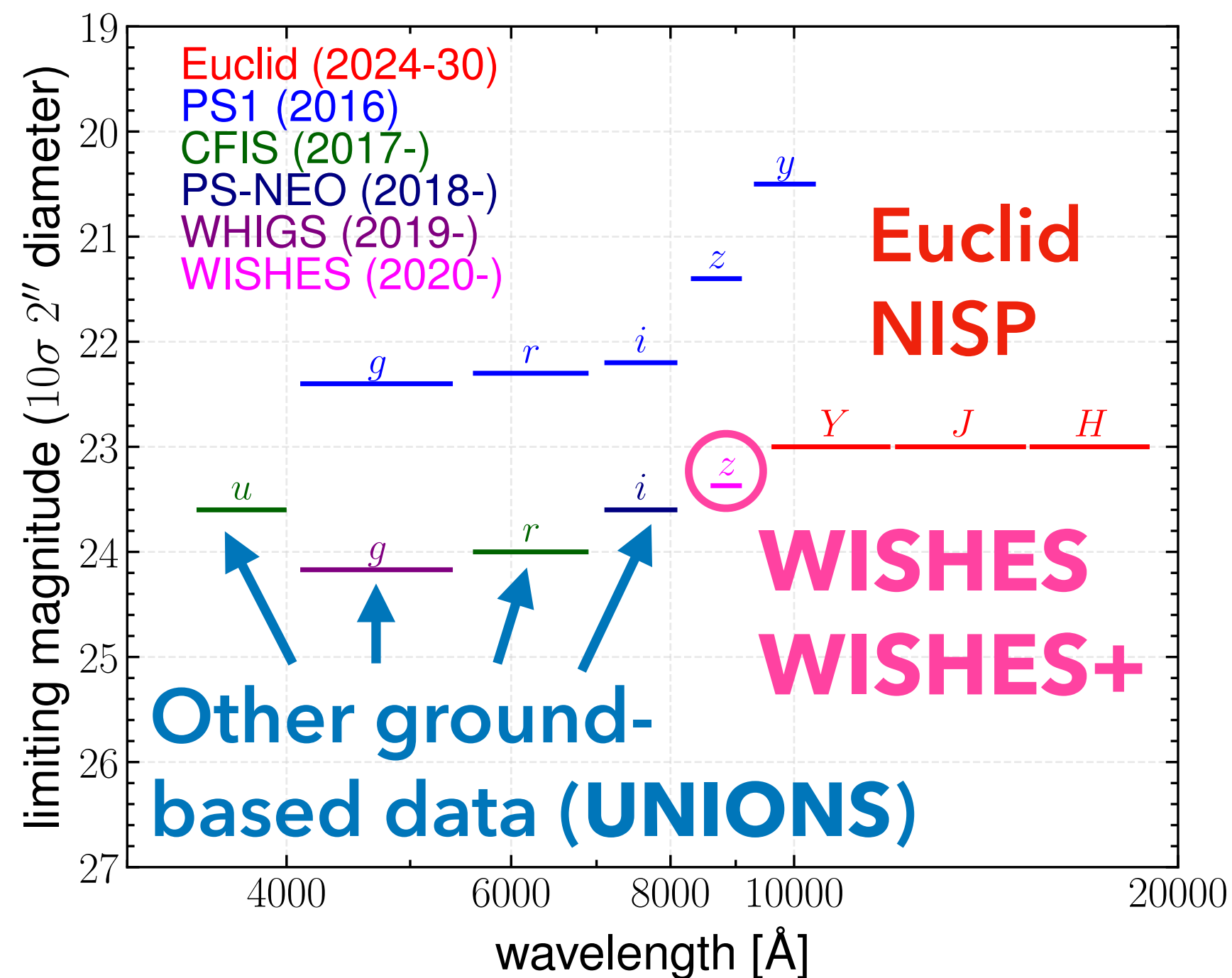
Timeline of Data Release

- Public data release of Q1 (Quick release; 53 deg²): Mar 2025
- Public data release of DR1 (~2,000 deg²): Oct. 2026



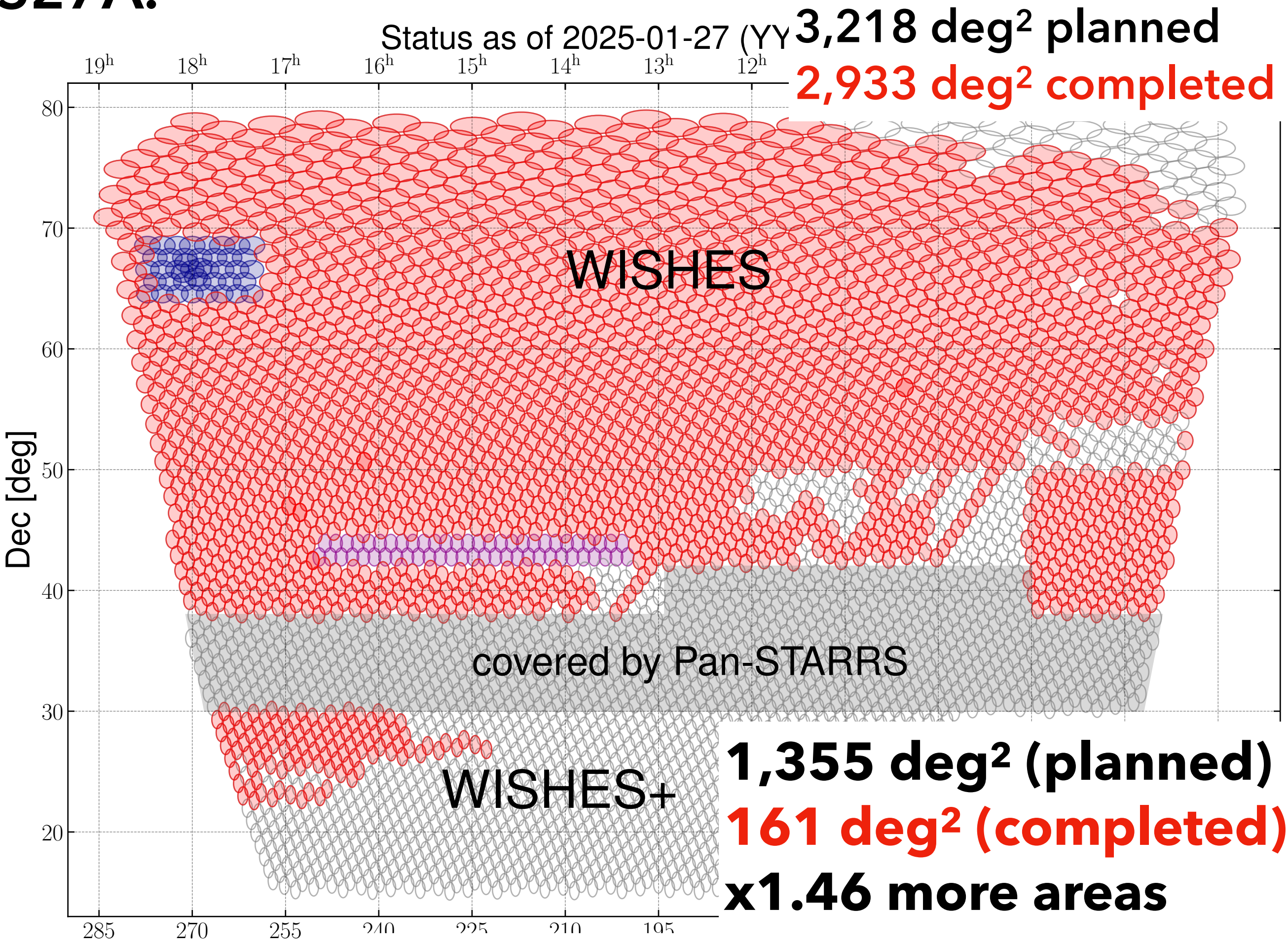
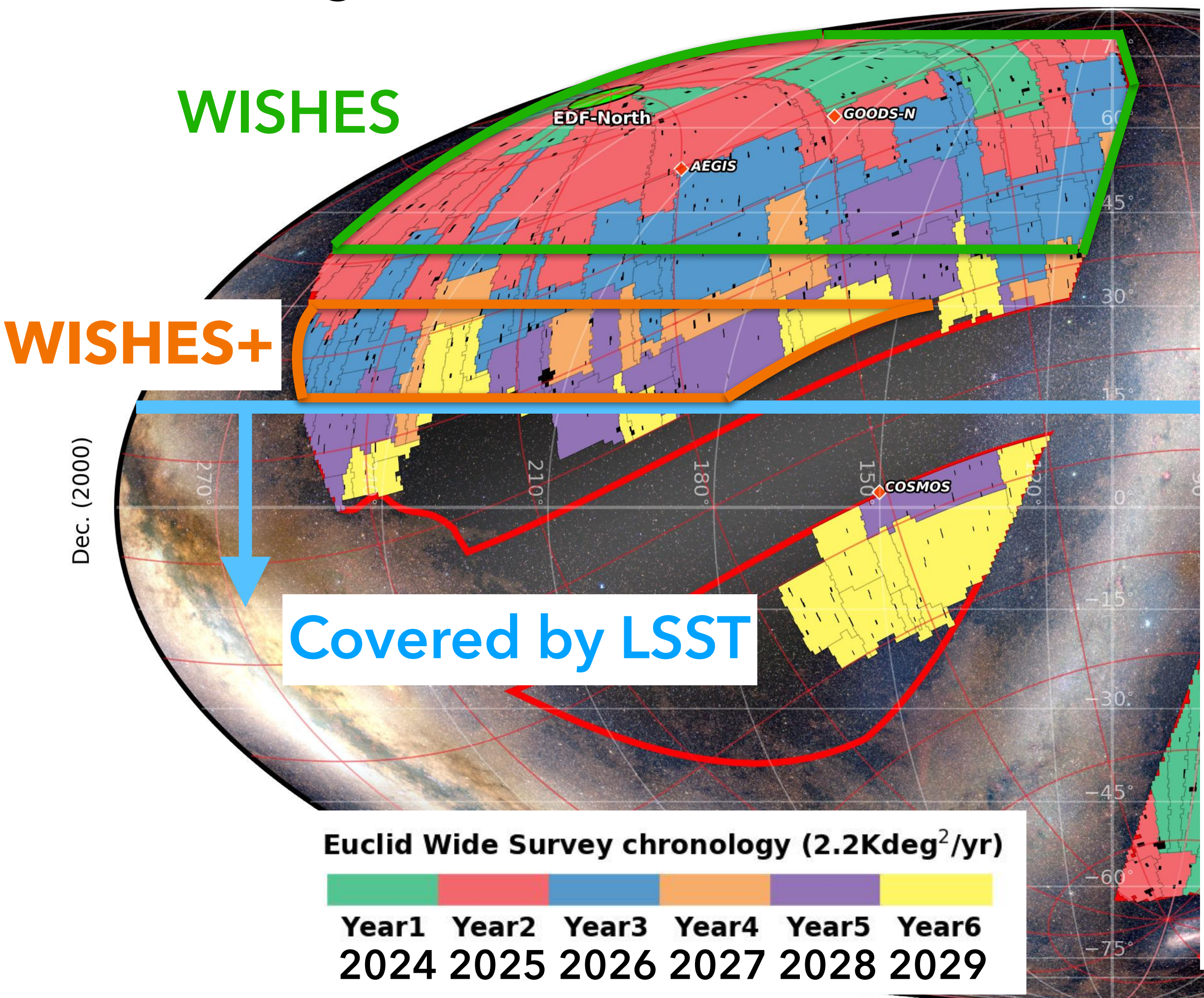
WISHES and WISHES+: z-band Survey for Euclid

- ◆ Wide Imaging with Subaru HSC of the Euclid Sky (WISHES): S20B-S24A (PI: M. Oguri)
 - Provide HSC z-band imaging data covering the northern footprint of Euclid Survey
 - (i) improve photo-z of source galaxies for **cosmic shear science**
 - (ii) search for rare objects such as **high-z quasars**
- ➡ The regions at $+15 \text{ deg} < \text{Dec.} < +30 \text{ deg}$ will not be observed by LSST nor WISHES.
WISHES+ will cover the missing sky and open up a synergy with ALMA.



Survey Footprints of Euclid and WISHES/WISHES+

◆ Extended Wide Imaging with Subaru HSC of the Euclid Sky (WISHES+; PI: K. Osato)
15.1 nights are allocated from S24B to S27A.



◆ WISHES+ region will be observed by Euclid **from 2026 (Year 3).**

Credit: Jean-Charles Cuillandre (CEA)

R.A. (2000)

Current Observing Status of WISHES/WISHES+

- **WISHES**

Planned area (w/ PS1): **3,218 deg²**

Planned area (w/o PS1): **4,400 deg²**

Observed area: **2,933 deg²**

Completion rate:

66.7% (w/o PS1), **91.2%** (w/ PS1)

Completing WISHES (S25A; PI: M. Oguri)
will observe the remaining region.

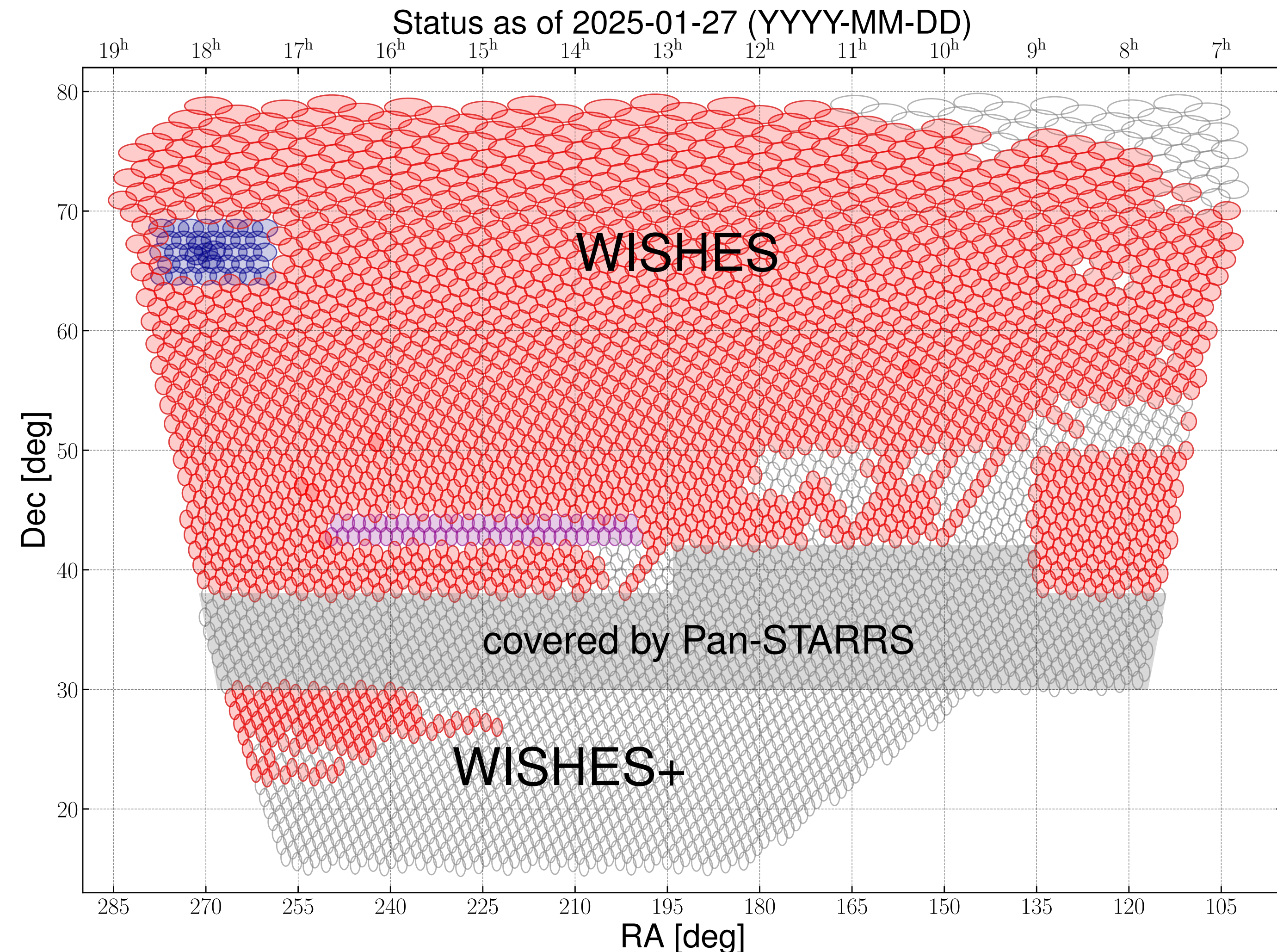
- **WISHES+**

Planned area: **1,355 deg²**

Observed area (as of today): **161 deg²**

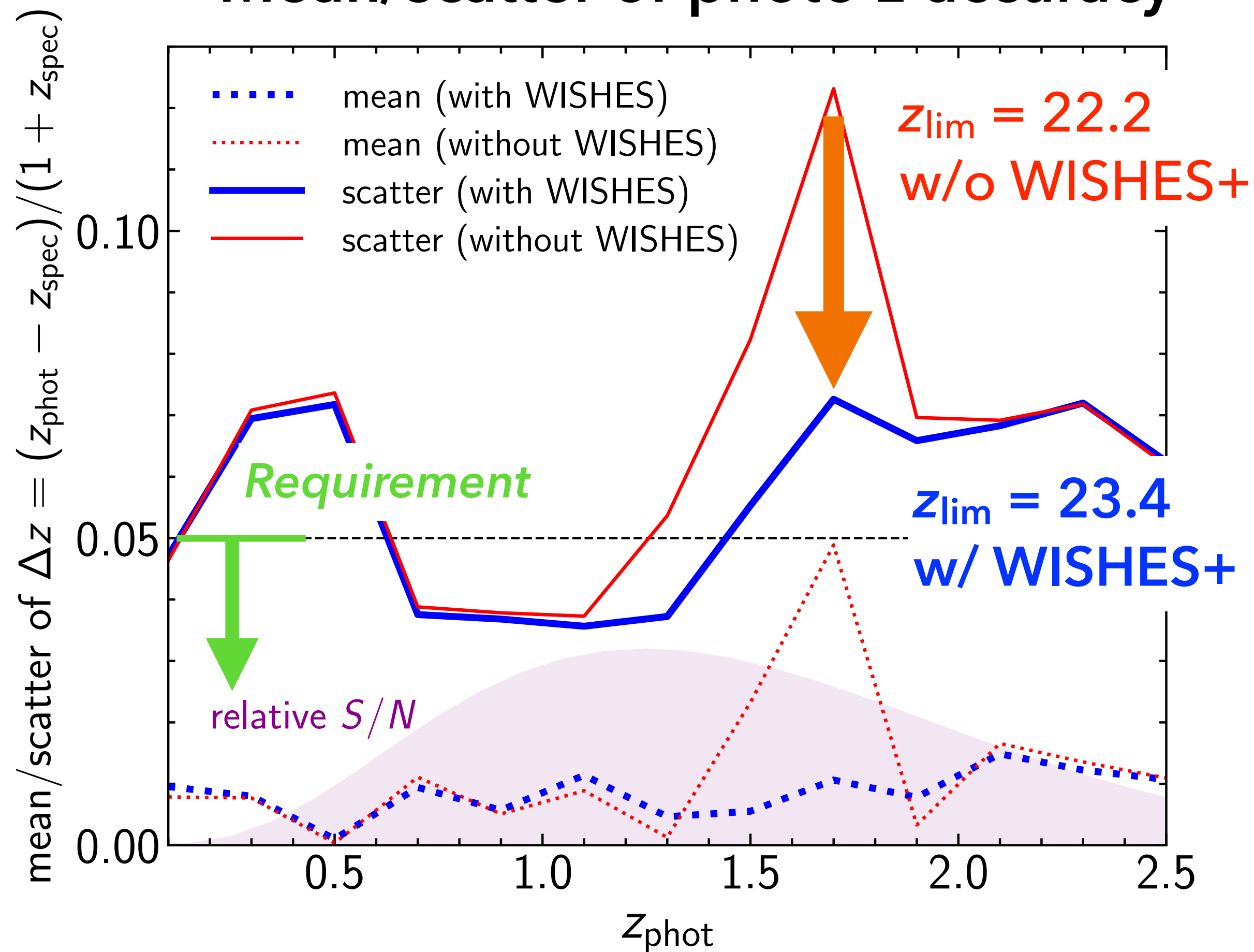
Completion rate: **11.9%**

N.B.: WISHES+ region is more visible
in spring semester. We will request more
nights should be allocated
in spring semesters.

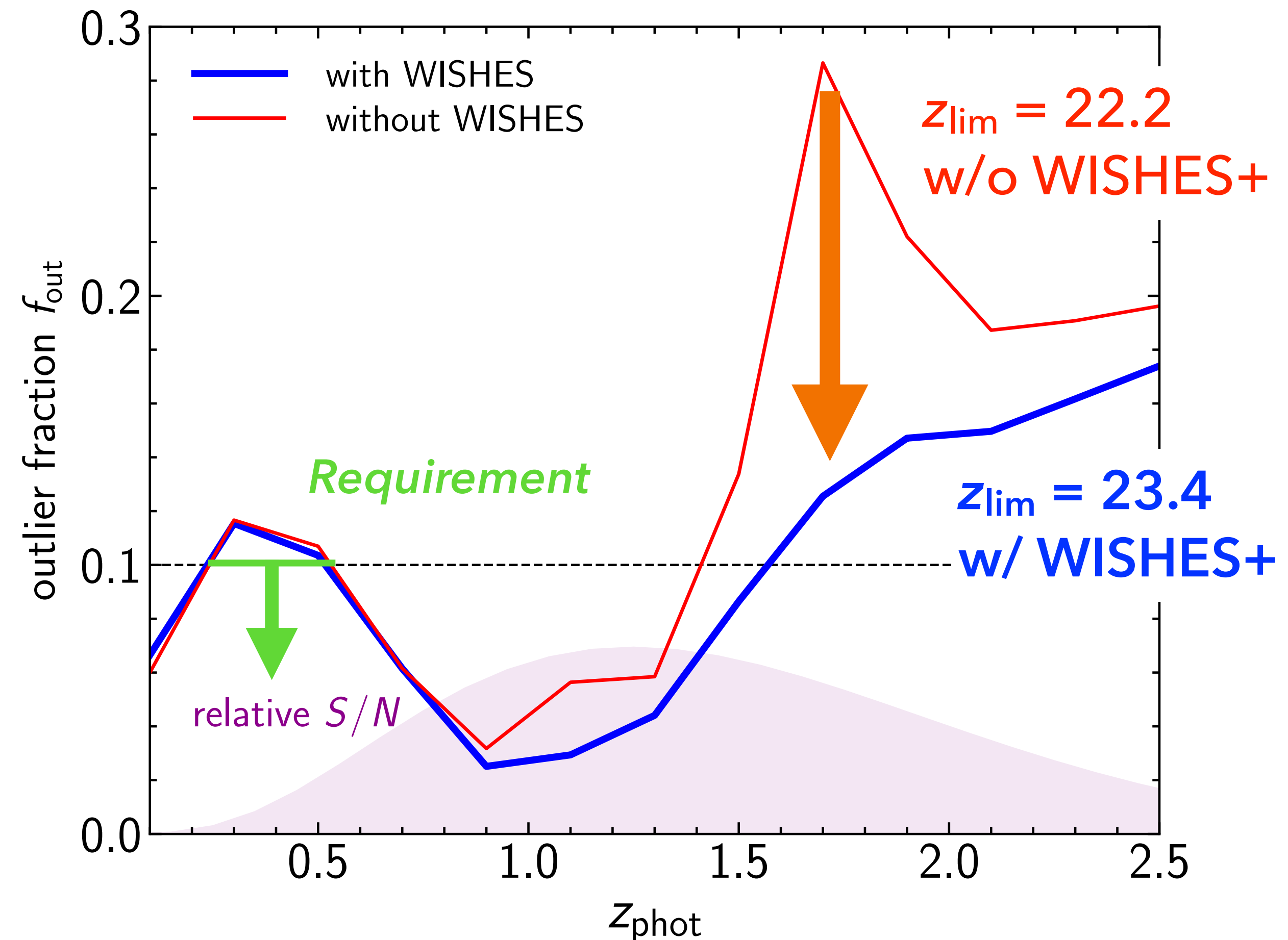


Improving Photo-z for Cosmic Shear Cosmology

• Mean/scatter of photo-z accuracy



• Outlier fraction

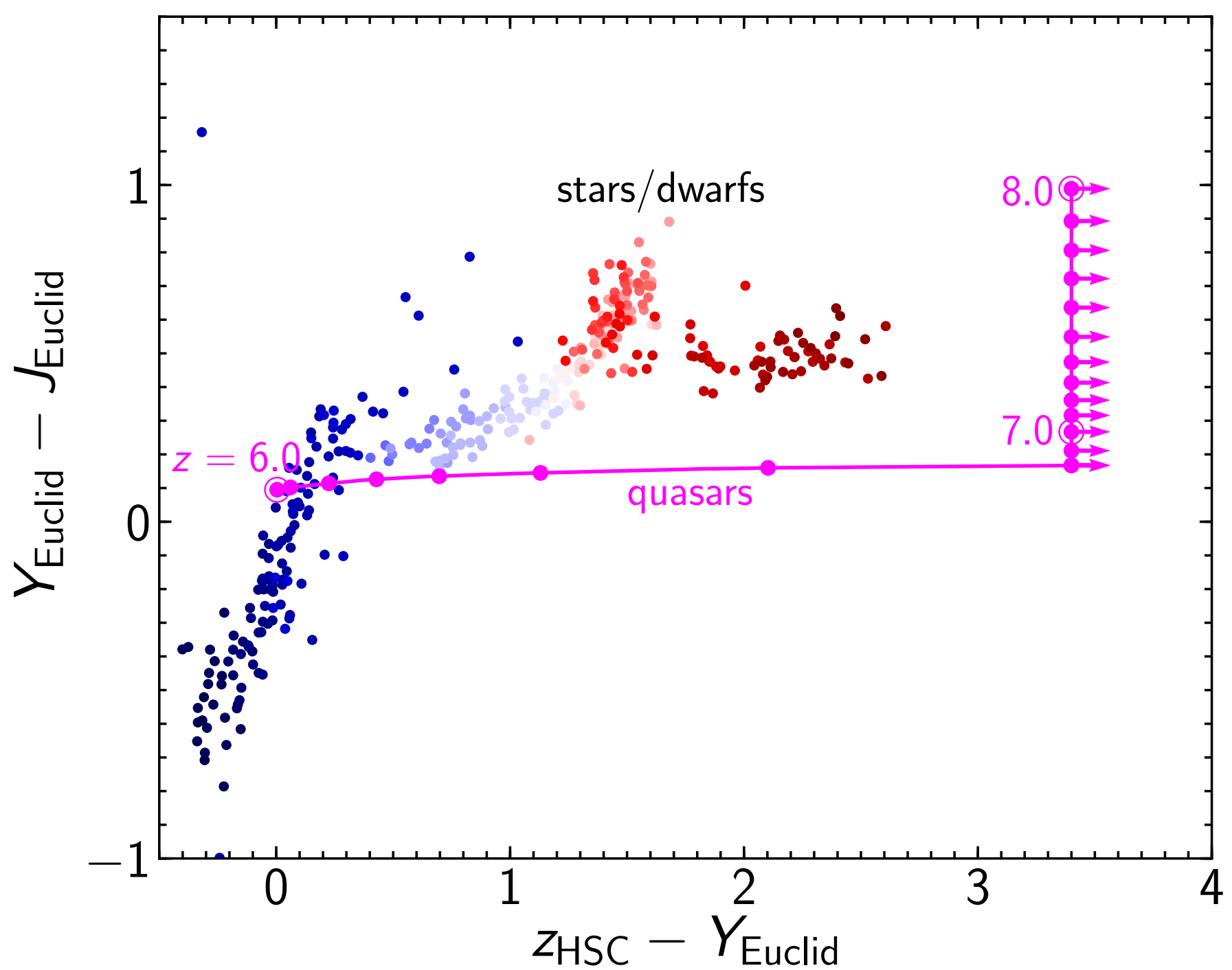


◆ **Blue lines:** Only z-band depth changed with depth of other bands (VIS+ugri+YJH) kept.
➡ **Without WISHES+, constraints on cosmo. params. would be degraded!**

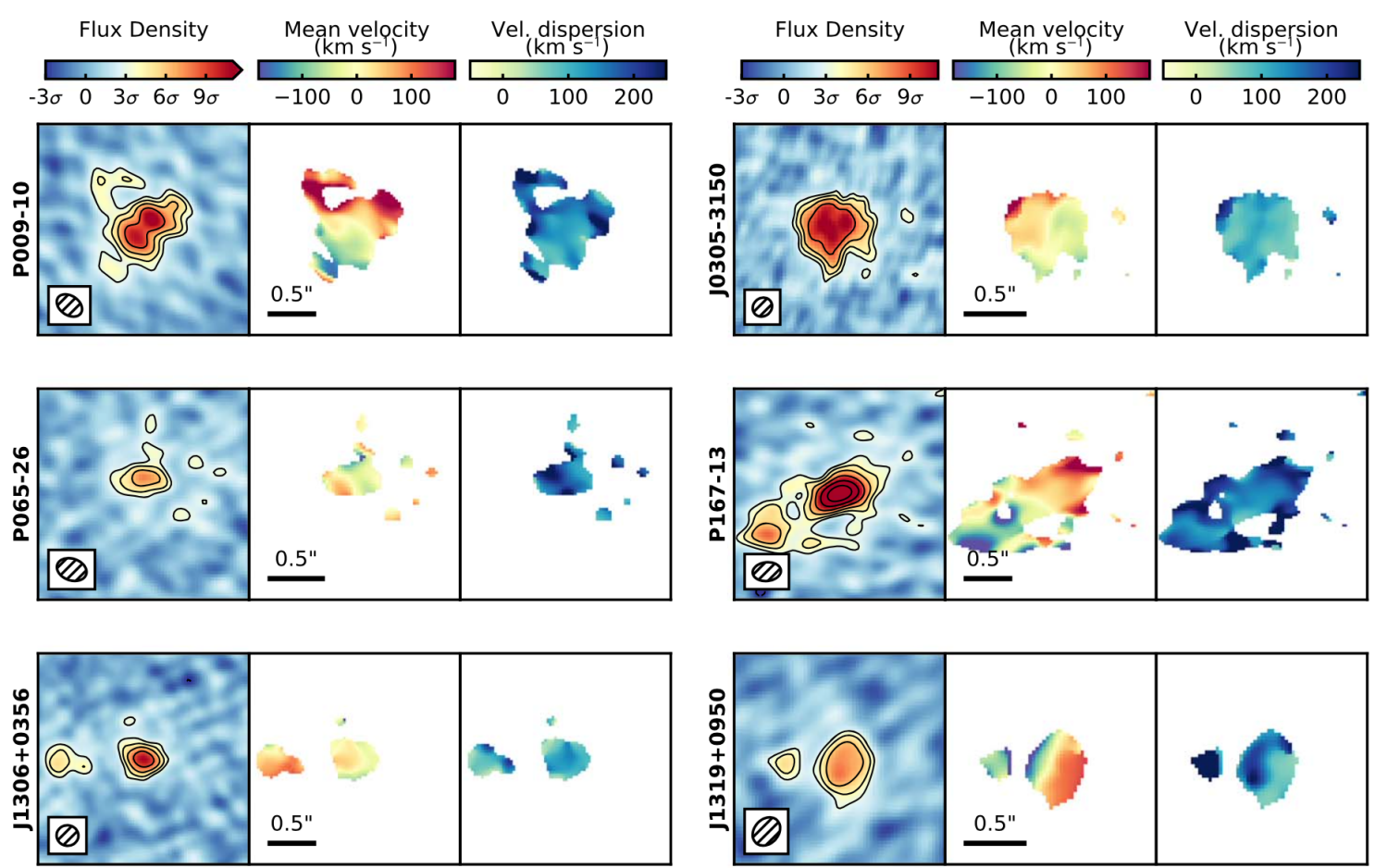
Search for High- z Quasars

◆ Deep z -band images are very important for efficient quasar search from Euclid.

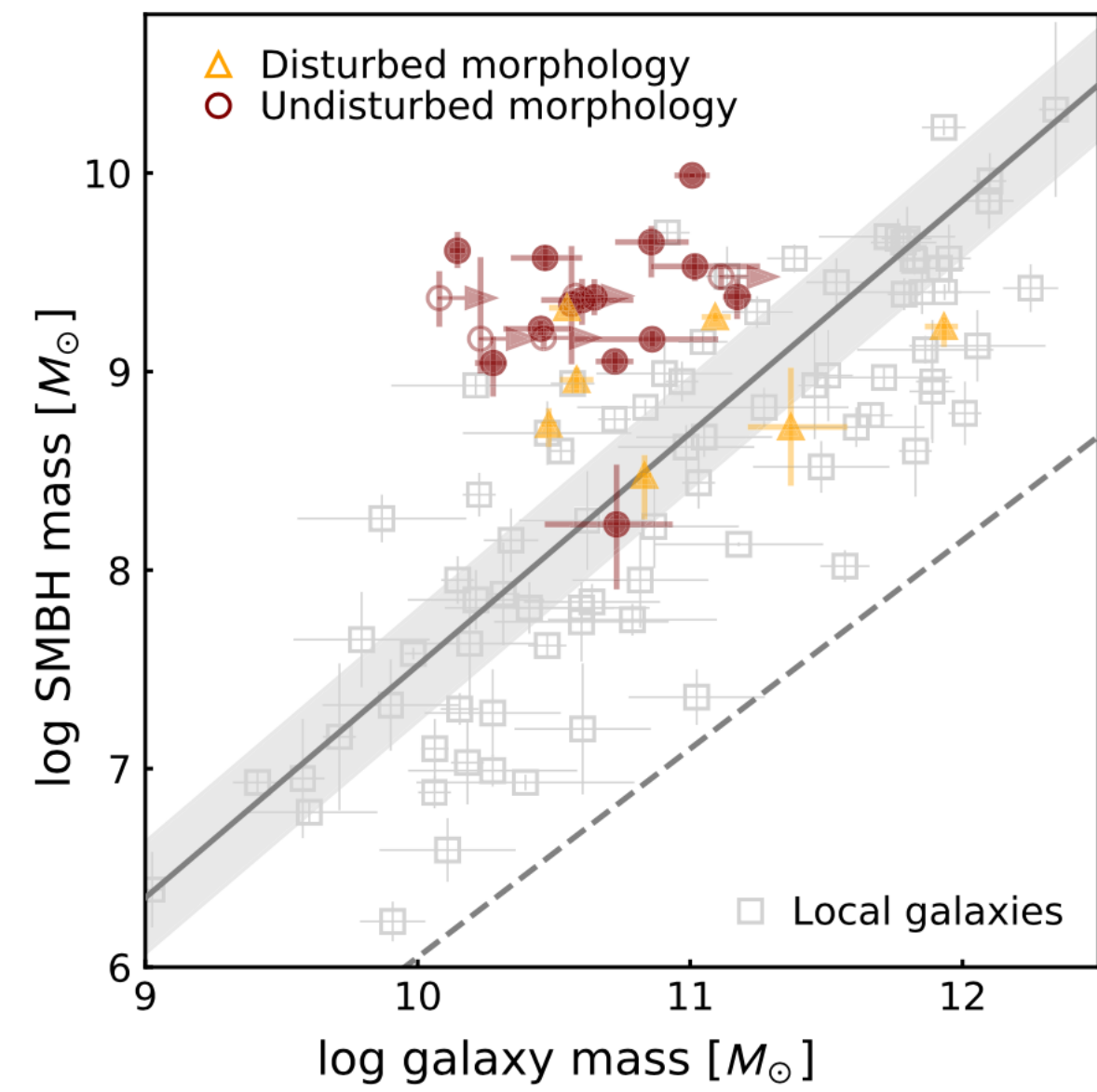
- WISHES + WISHES+ provide ~ 20 quasars at $7 < z < 7.5$, ~ 15 quasars at $7.54 < z$ (these numbers are limited by z -band depth!)
- We will start selections with the first UNIONS Grand Unified Catalog ($z_{\text{WISHES}} - y_{\text{PS1}}$), later replaced with Euclid Y .



◆ ALMA Host galaxy studies are only possible in the WISHES+ area.



Neeleman et al. 2021



2. WISHES+ Science with UNIONS



The Ultraviolet Near Infrared Optical Northern Survey is a collaboration of 4 scientific projects:

Hawaiian
Islands



Pan-STARRS
2 x 1.8m



CFHT
3.6m



Subaru
Telescope
8.2m

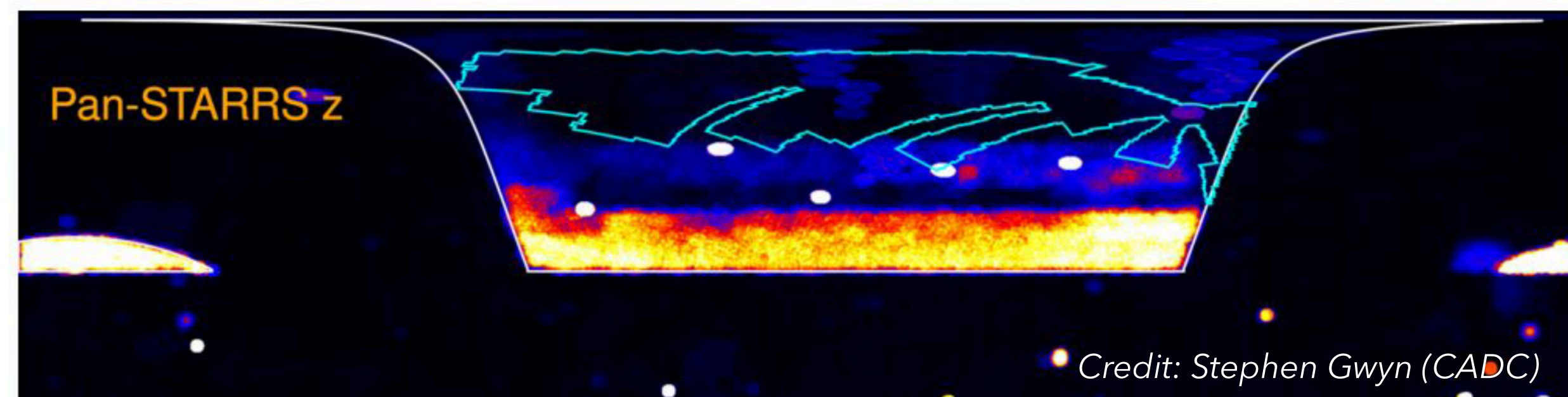
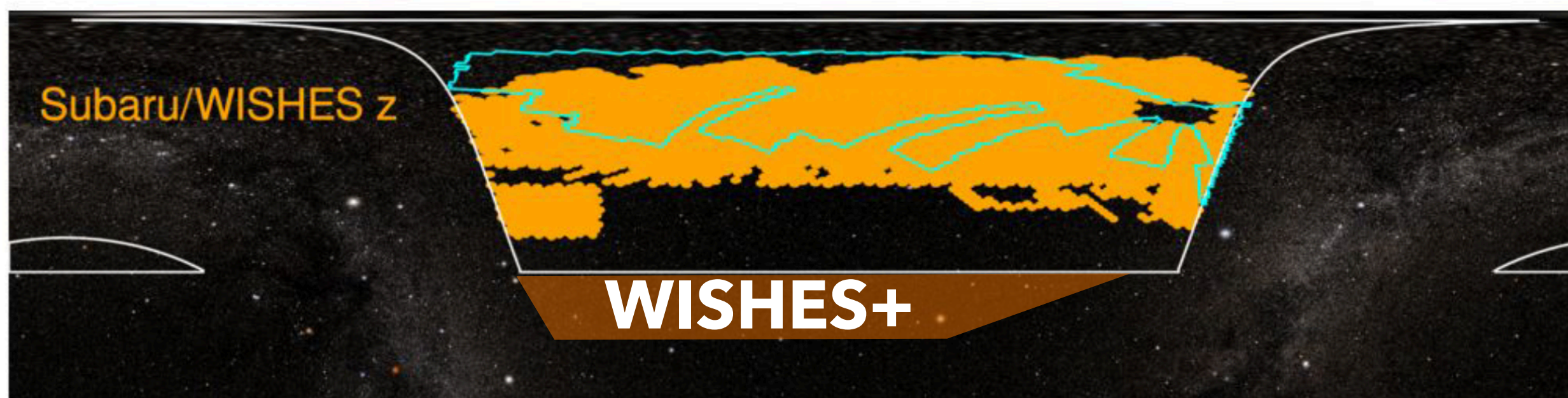
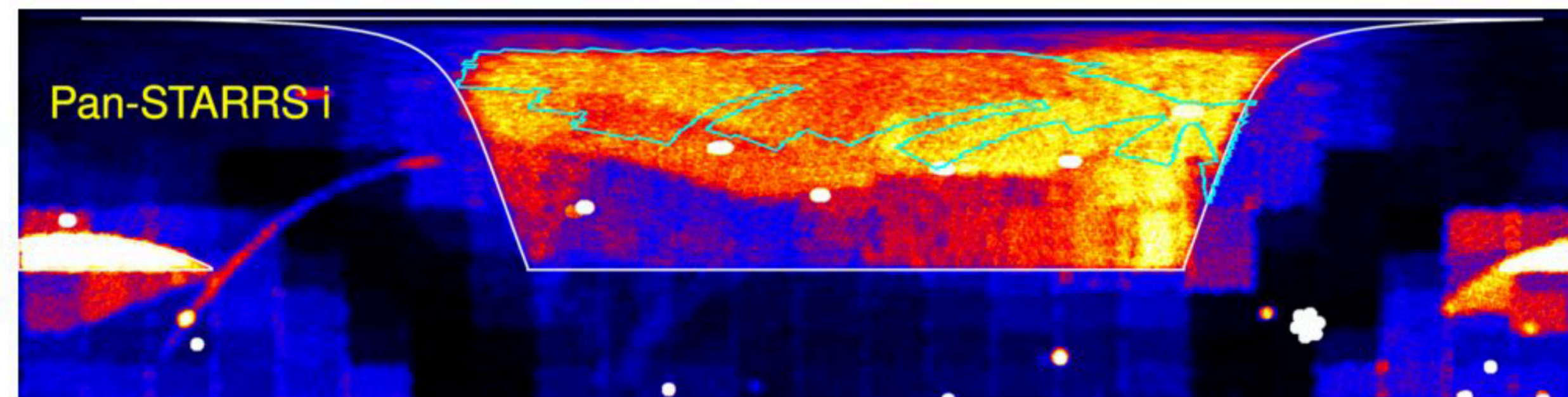
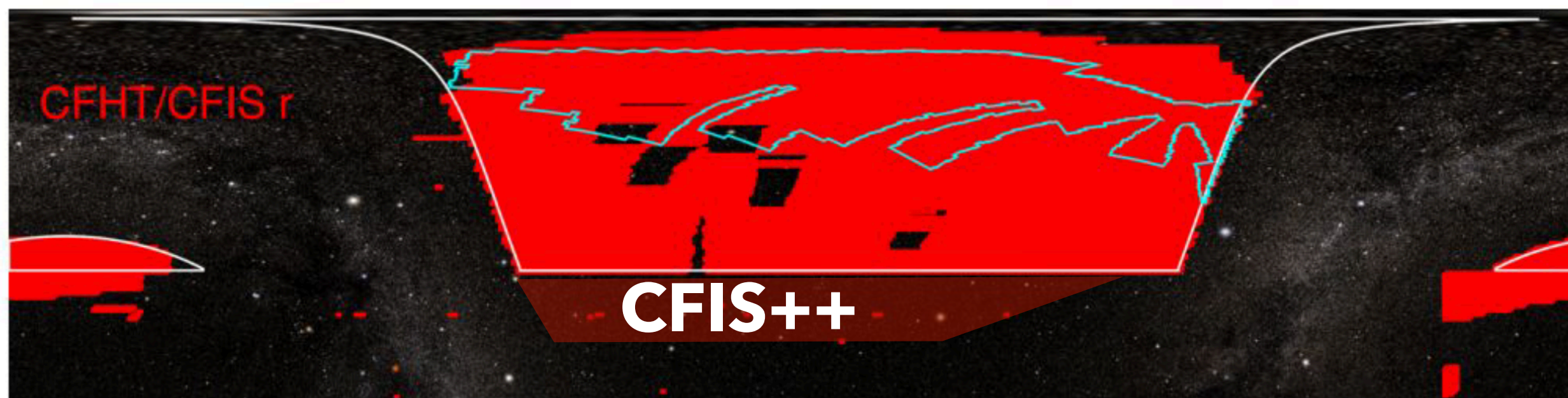
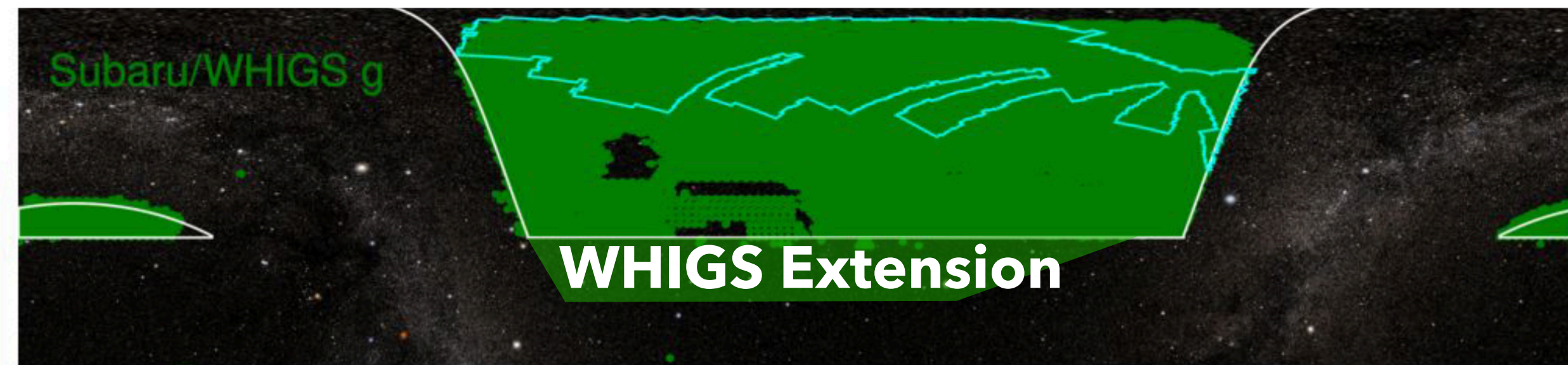


UNIONS

Hawaiian Alliance of ground-based telescopes:

CFHT/CFIS(++) (u, r), **Subaru/WISHES(+)** (z), Subaru/WHIGS (Extension) (g), Pan-STARRS (i, z)

UNIONS Survey paper will come out soon.



Credit: Stephen Gwyn (CADC)

UNIONS Results

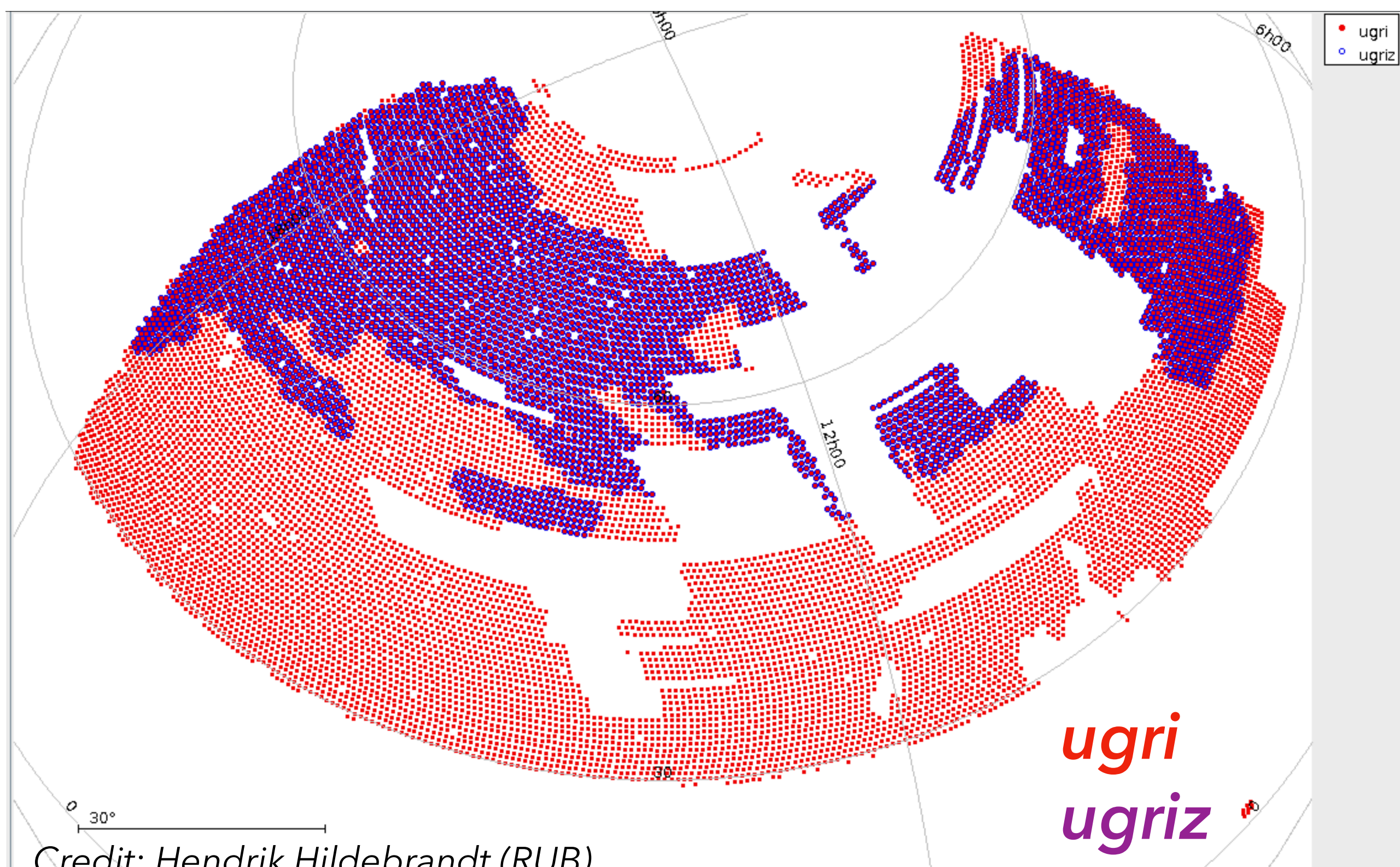
◆ Stand-alone science projects with UNIONS data

- UNIONS Grand Unified Catalog

- ➡ Deep multi-band catalog

Current area: $>3,000 \text{ deg}^2$ (*ugri*)

$>1,200 \text{ deg}^2$ (*ugriz*)



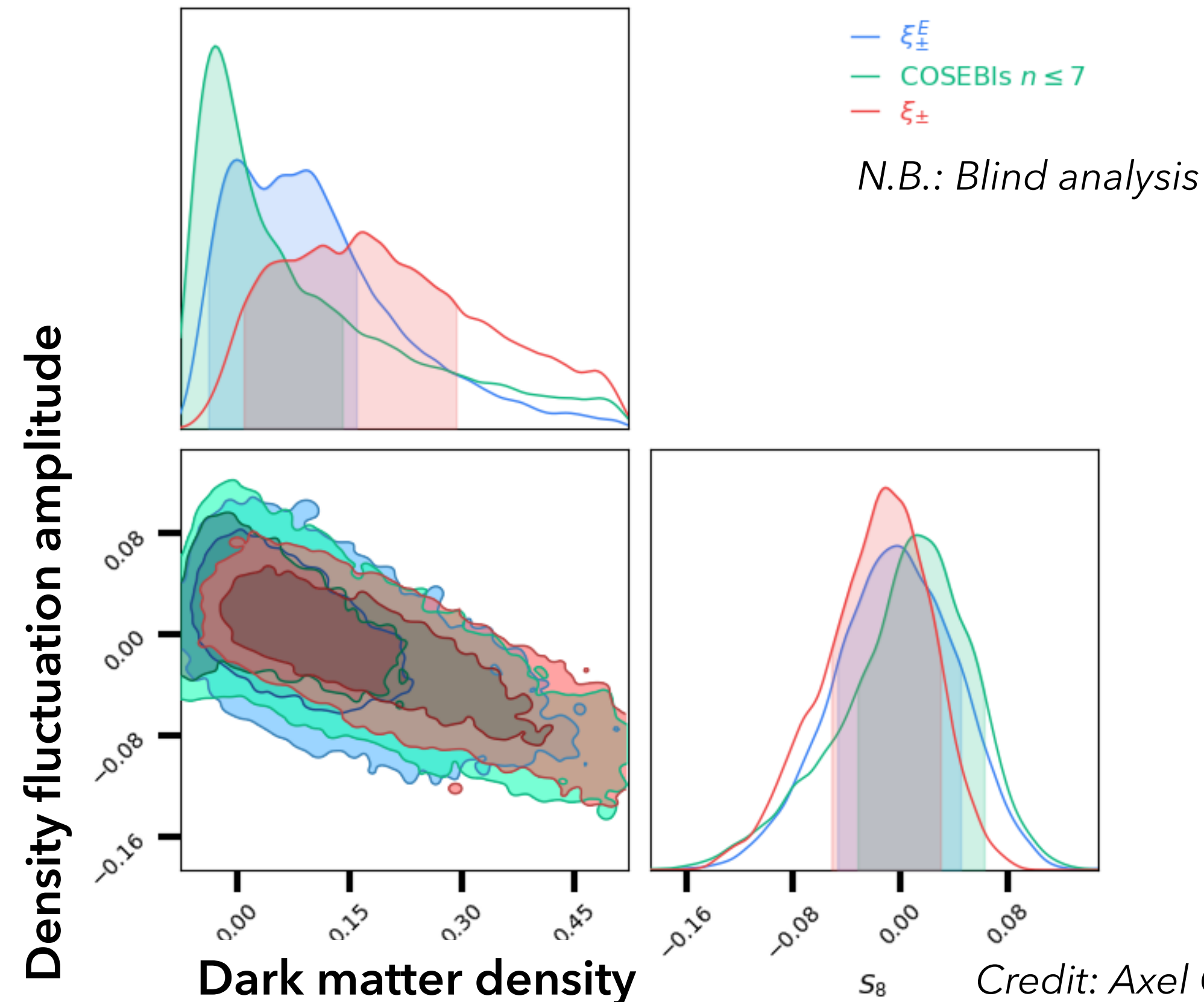
Credit: Hendrik Hildebrandt (RUB)

- UNIONS WL

- ➡ Precursor of Euclid WL

Current area: $1,440 \text{ deg}^2$

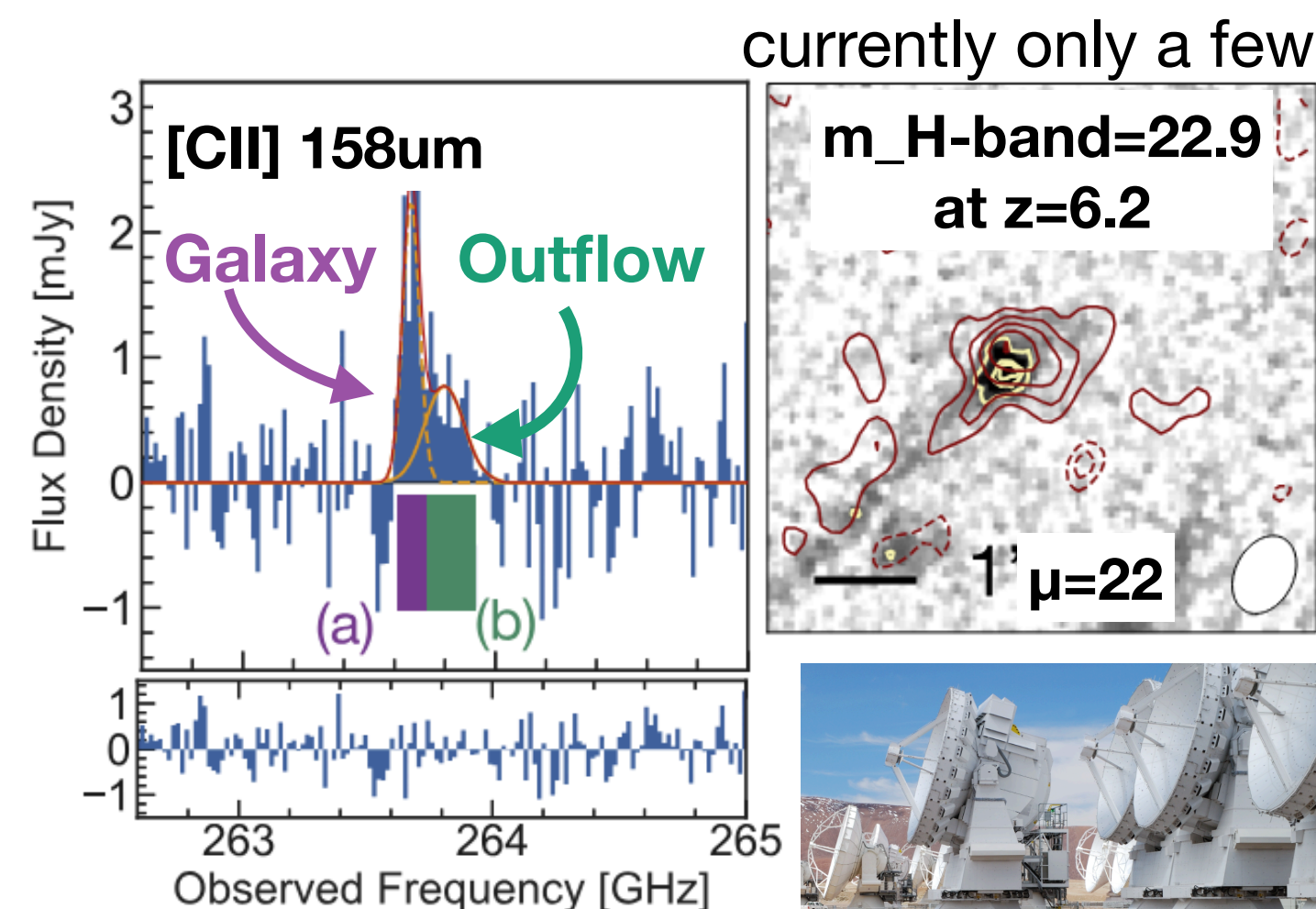
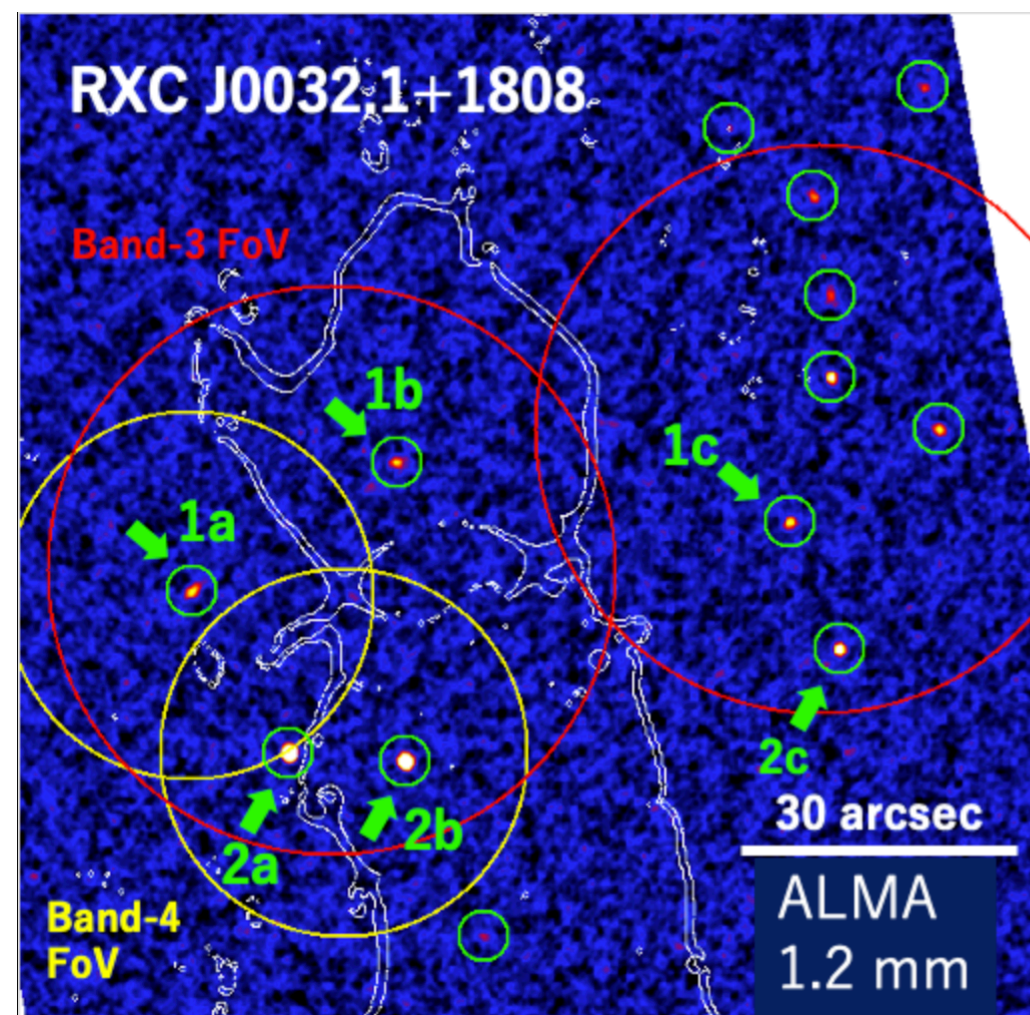
Source density: $6.73 \text{ gals/arcmin}^2$



Credit: Axel Guinot (CMU)

Multi-Wavelength Synergy with ALMA and TMT

- ◆ WISHES+ unlocks synergy with ALMA and future large telescope in northern sky.
- Searches of :
 - Massive high-redshift galaxies ($\sim a \text{ few } \times 10,000$)
 - Highly lensed galaxies ($\sim 16,000$ clusters expected in WISHES+ area)
- ◆ Euclid + WISHES/WISHES+ will provide unique opportunity to study high- z galaxies in great details.



Representative Inputs
for the future telescopes,
such as TMT



(Left) ALMA survey of lensing cluster (Right): Emission observation of lensed galaxies

Summary

- **WISHES+** is the deep z-band survey for Euclid and stand-alone science. In combination with WISHES, the total survey area reaches **4,550 deg²**. Its legacy value is high; the data can be used for many years in various fields.
- WISHES+ observes the sky at lower latitudes ($+15 \text{ deg} < \text{Dec.} < +30 \text{ deg}$), which overlaps the area visible from **multi-wavelength telescopes: ALMA and TMT**.
- WISHES+ observations are going well; the current observed area is 161 deg² and the completion rate is 11.9%. The rest will be completed in the next 4 semesters.
- We are working with other UNIONS surveys (CFIS, WHIGS, and Pan-STARRS). The synthetic multi-band catalogues can be used not only for Euclid's science but for stand-alone science projects in multiple areas.

Appendix

Recent Activities of JEC and UNIONS in Japan

- **Japanese Euclid Consortium**

The contribution from WISHES/WISHES+ grants access to Euclid's data for 35 PIs. Each PI can assign two junior members (students or PDs), who also can get access.

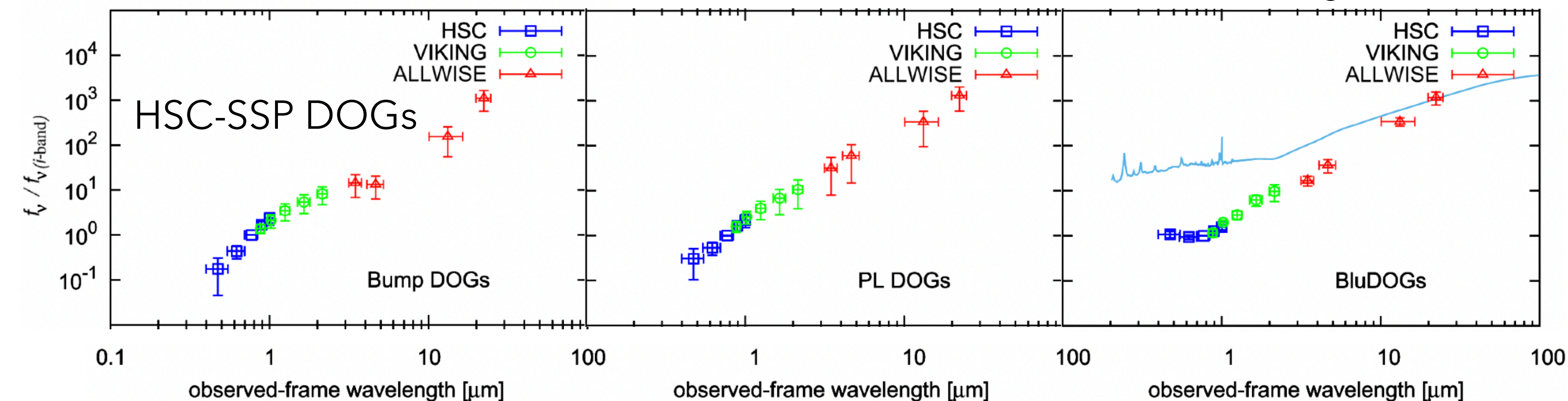


*JEC Meeting 2024
KMI, Nagoya University; Nov. 25-26, 2024*

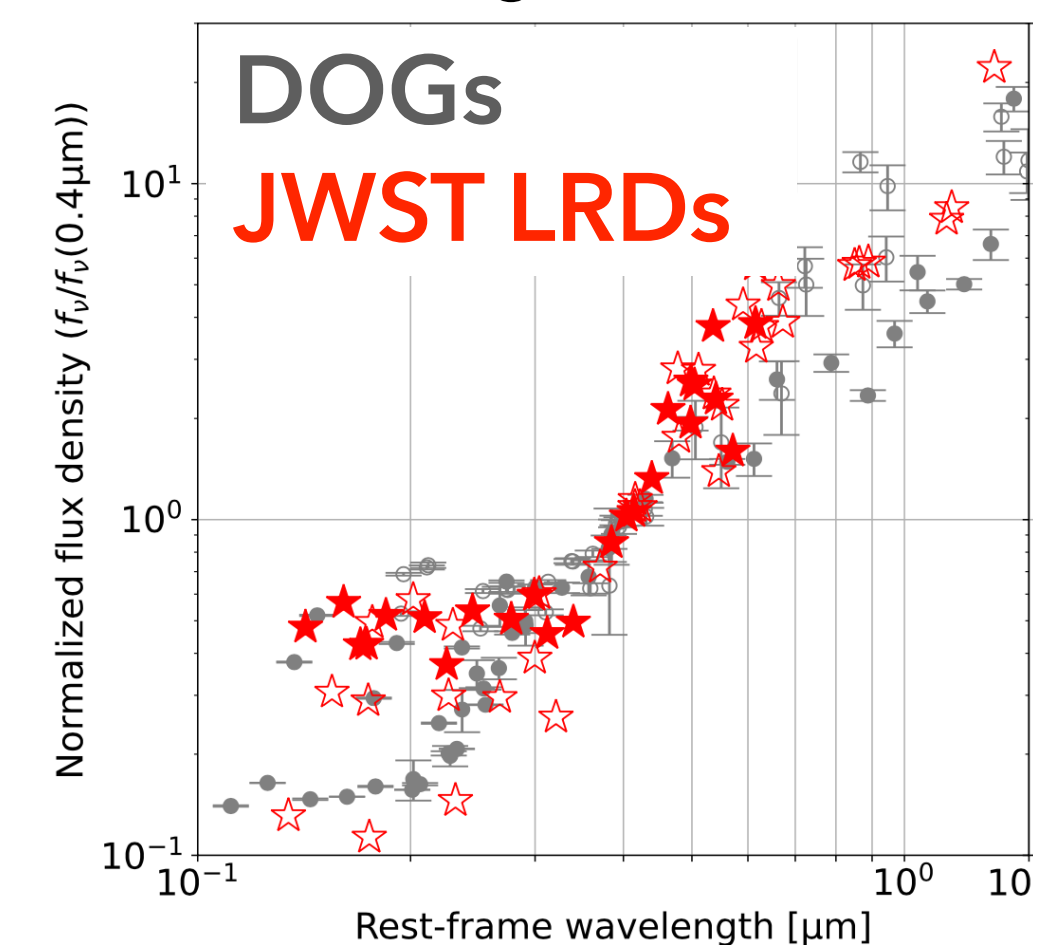
Ongoing WISHES surveys of rare AGN

- ◆ **Dust Obscured Galaxies (DOGs):** an AGN pop. between dusty starburst and quasar
 - 3,700 DOGs selected from the current UNIONS catalog of 800 deg² (w/o WISHES-z; Yoshida, Nagao et al. in prep.)
 - DOGs could be lower-z counterparts of JWST “Little Red Dot (LRD)” AGN
- ◆ WISHES+ characterizes the sub-population at different evolution stages
 - Deep NIR catalog available in WISHES+ area
- ◆ **Radio galaxy search (u/g/r/i-dropout)** also ongoing (Ide, Nagao et al. in prep.)

Noboriguchi et al. 2019



Noboriguchi et al. 2023



Details of Observations

- Observation conditions:
seeing < 1.0'', transparency > 0.7, gray,
>30 deg from moon
- Following HSC Wide observing strategy,
3 dithers for each pointing, 80 sec exposure for each
Effective area of a pointing: 1.46 deg²
- 105.5 hours (~= 15 nights with weather factor)
in HSC Queue mode (assuming 10 hours = 1 night, weather factor = 0.7)
- WISHES pointings are given higher priority.

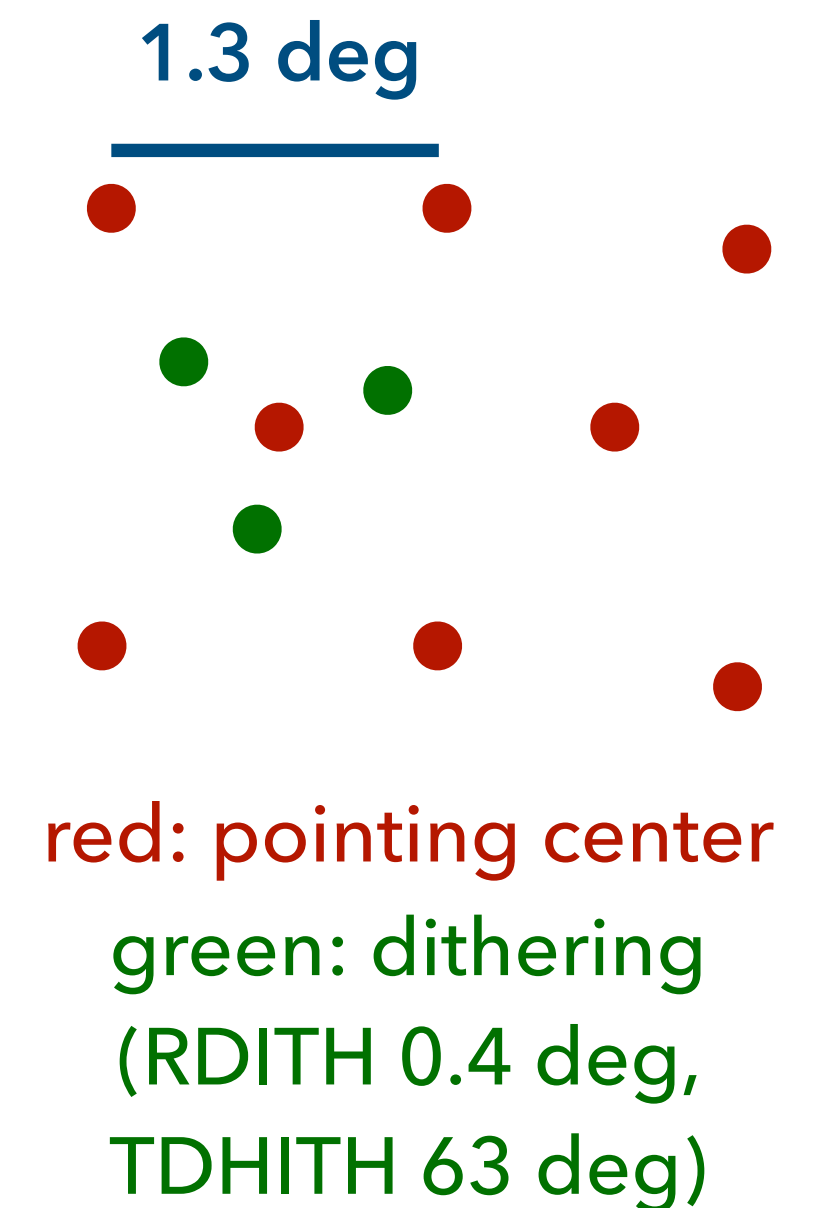
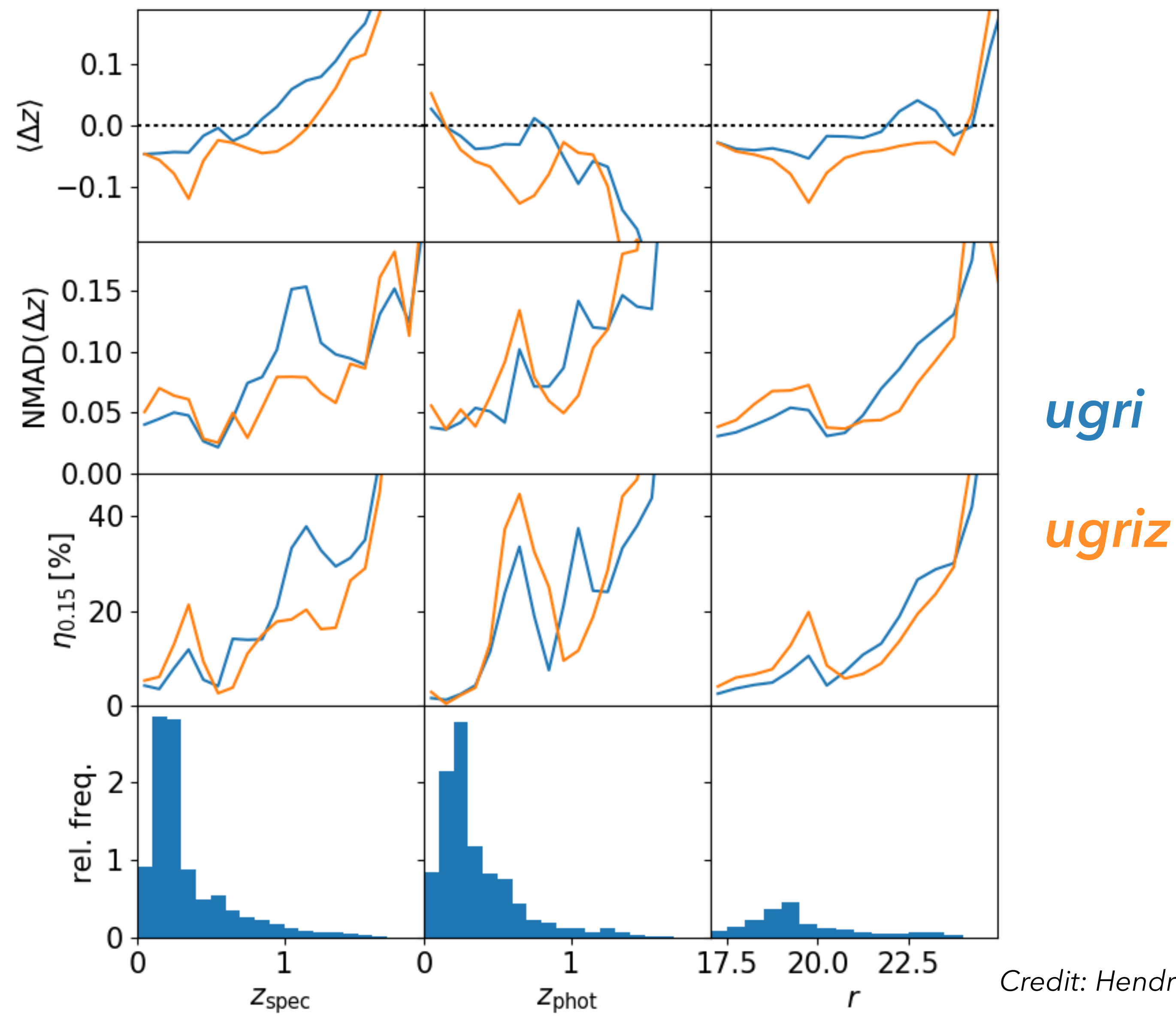
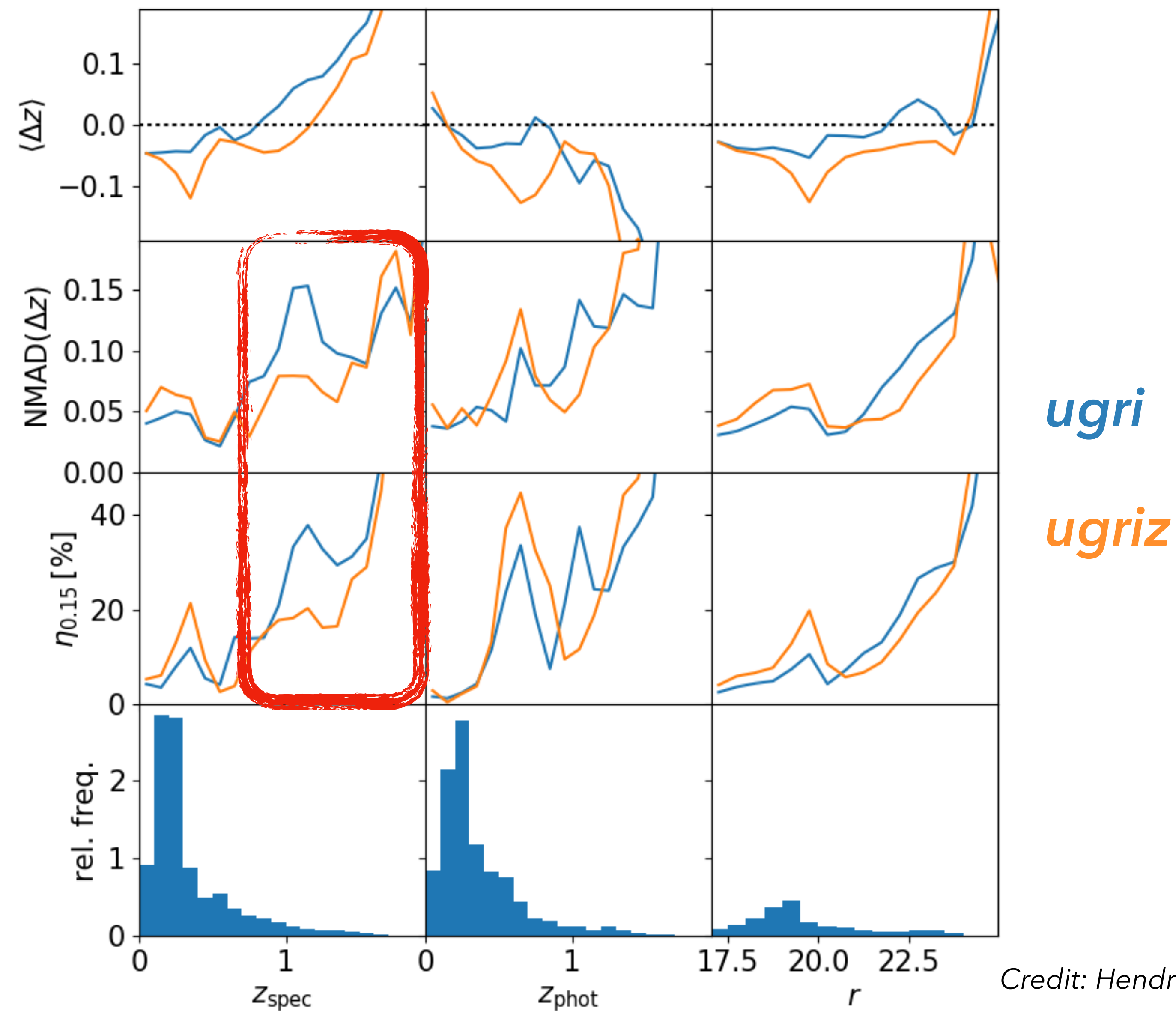


Photo-z in UNIONS Grand Unified Catalog



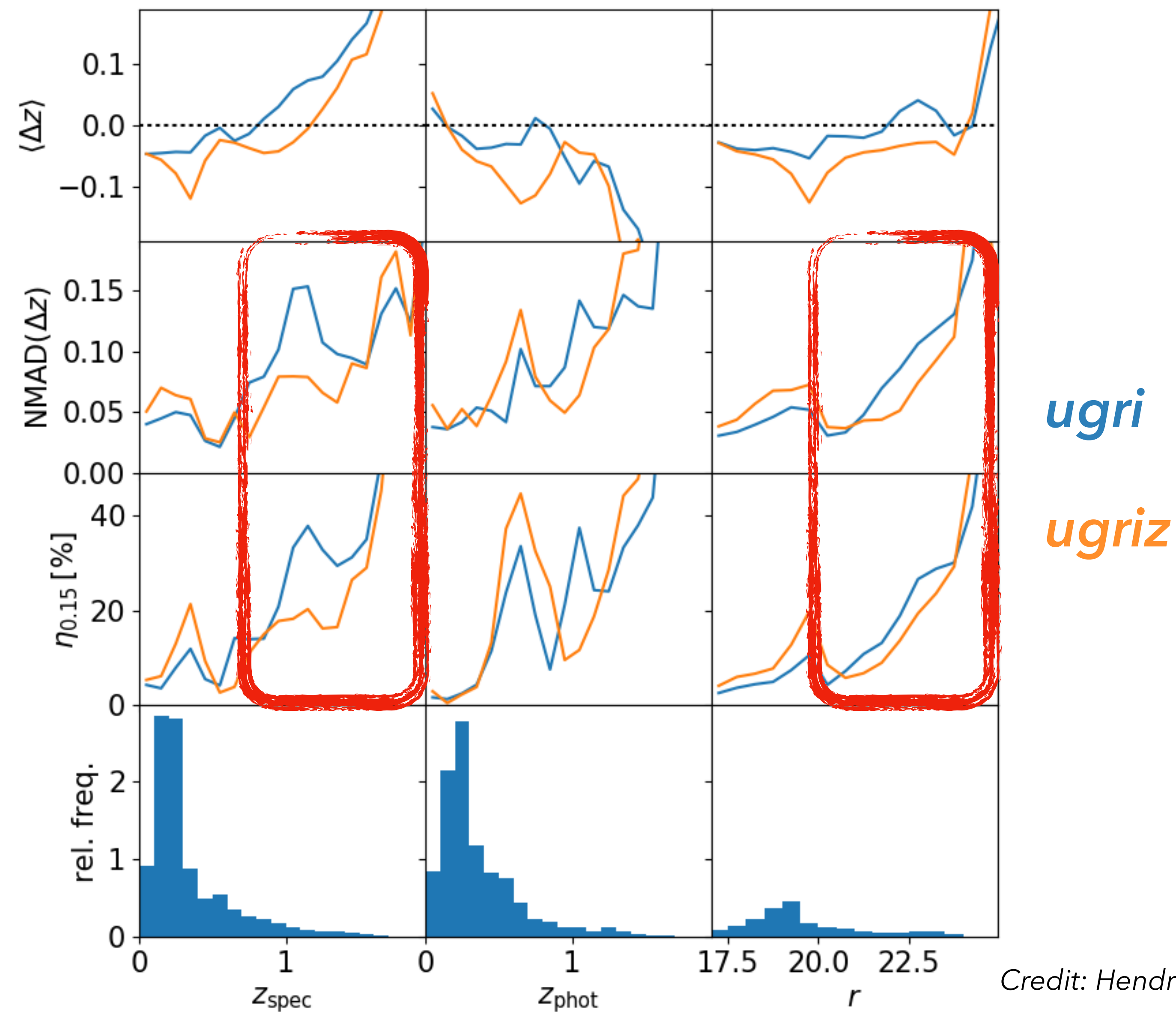
Credit: Hendrik Hildebrandt (RUB)

Photo-z in UNIONS Grand Unified Catalog



Credit: Hendrik Hildebrandt (RUB)

Photo-z in UNIONS Grand Unified Catalog



Credit: Hendrik Hildebrandt (RUB)

Other Science Cases

- Optical counterpart of GW sources
Identification of neutron star mergers is important for studies on origins of *r*-process elements.
➔ **Deep reference image is critical.**
- Probing MW structures
The tidal stream of the last major merger of MW (Gaia-Sausage-Enceladus) is expected to lie within WISHES+ footprint.
➔ **Understanding the kinematics and chemistry of MW**
- Finding strong lenses, cluster sample up to $z = 1, \dots$

