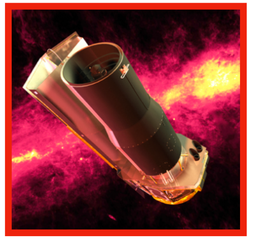
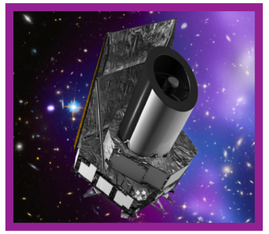
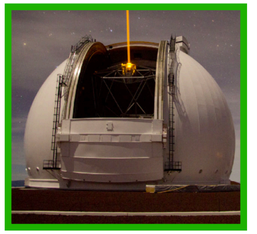
The Hawaii Two-0 Twenty Square Degree Survey:

Synergy with Next Generation Space Telescopes







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Roadmap

1. What is the Hawaii Two-0 (H20) survey?
   - Survey characteristics
2. Opportunities for synergy between Hawaii Two-0 & upcoming missions like Euclid, Roman, & JWST
   - Photometric redshift assessment
3. Hawaii Two-0 data products
   - Expected releases and dates

The Hawaii Twenty Square Degree Survey (H20)

An ultra-deep (AB mag < 27.5) survey covering two 10 deg² fields: North Ecliptic Pole (NEP), Euclid Deep Field Fornax (EDFF)

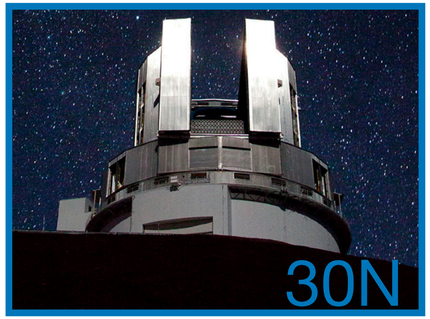
Primary Data (prior to 2022):

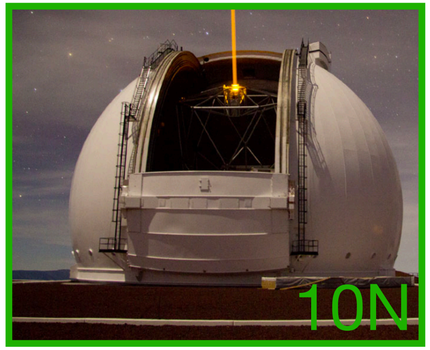
Subaru Hyper Suprime-Cam (HSC) *grizy*

Keck DEIMOS spectroscopy

Spitzer Mid Infrared Imaging [3.6μm], [4.5μm]

CFHT MegaCam u-band





After 2022:

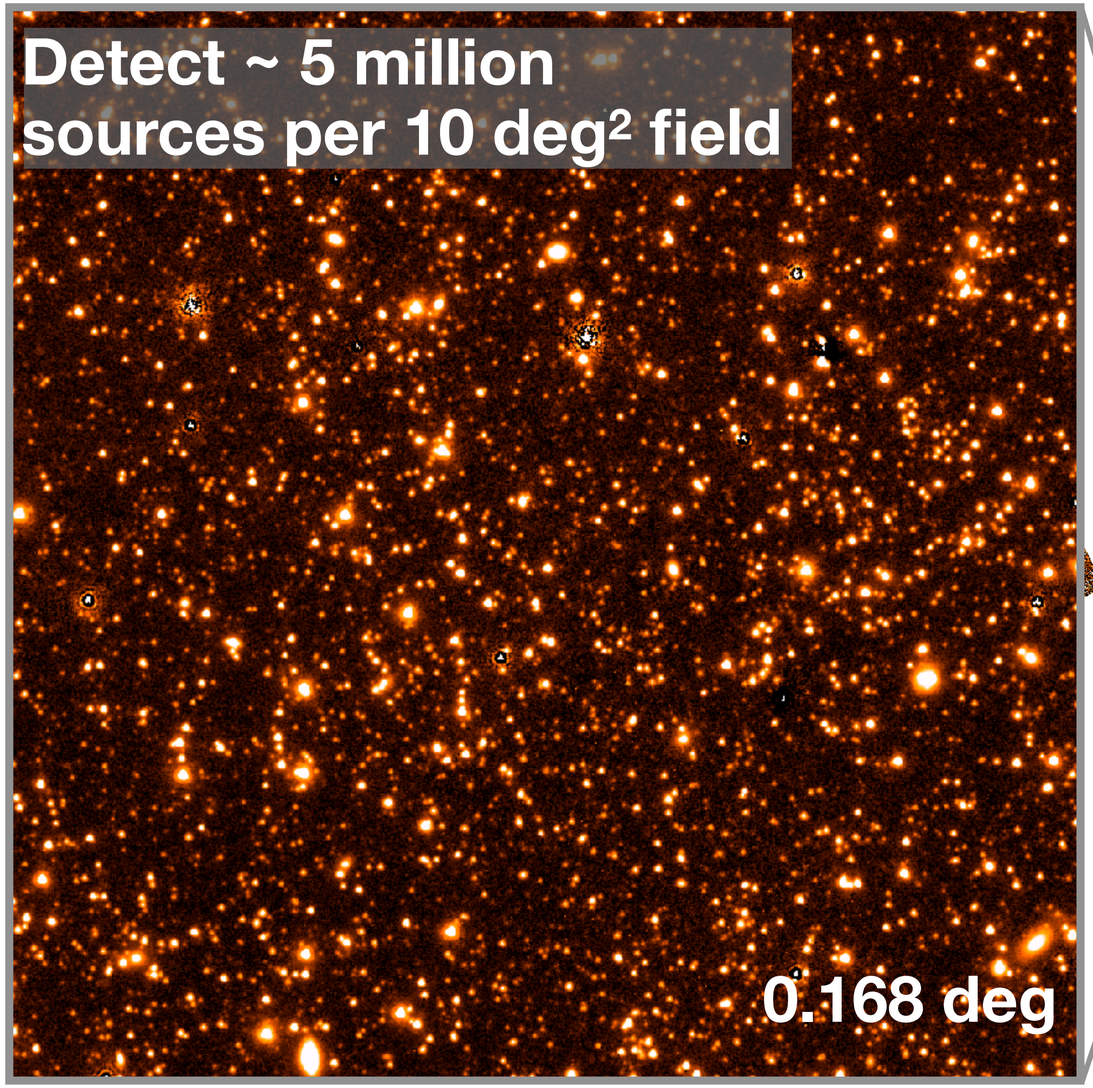
Deep Euclid YJH imaging

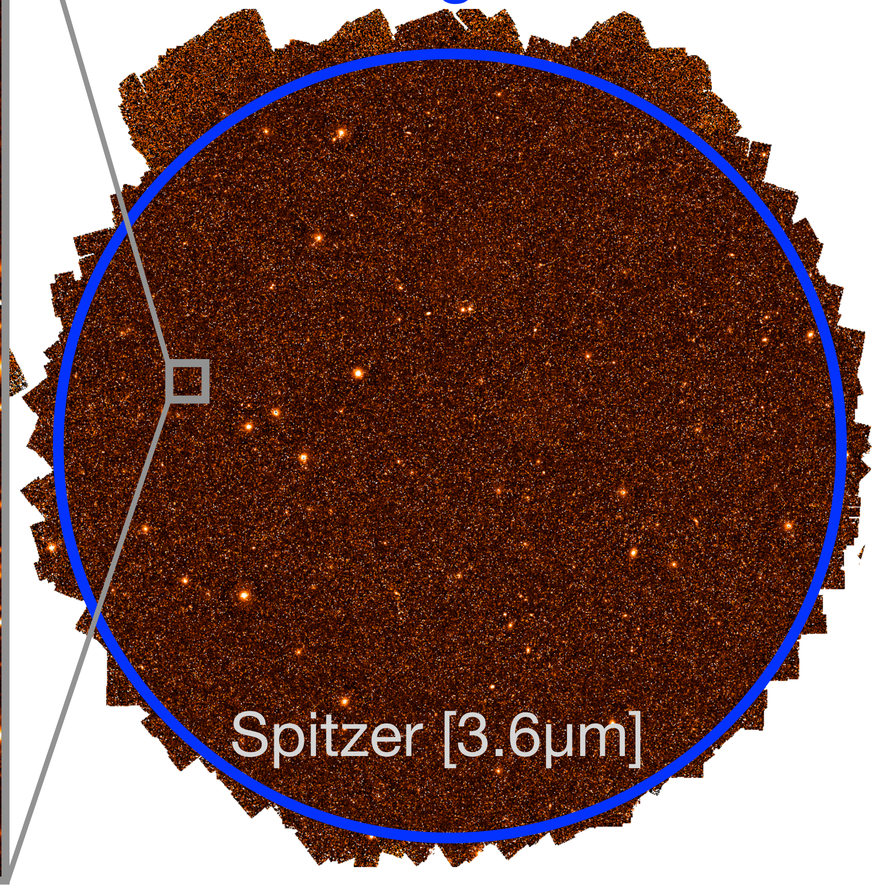
- NEP + EDFF are the primary calibration fields of the mission

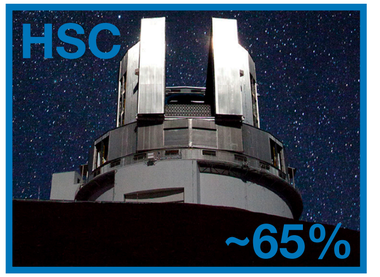
H20 Survey Status

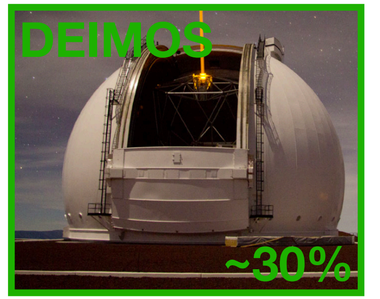
Filter	$u^{\dagger}$	g	r	i	z	YJH^{*}	[3.6μm]	[4.5μm]
Mag. Limit (5σ)	26.2	27.5	27.5	27	26.5	26	24.8	24.7

† Observations to begin in 2021A
* Observations to begin after launch of Euclid









The Hawaii Twenty Square Degree Survey (H20)

Immediate Goals:

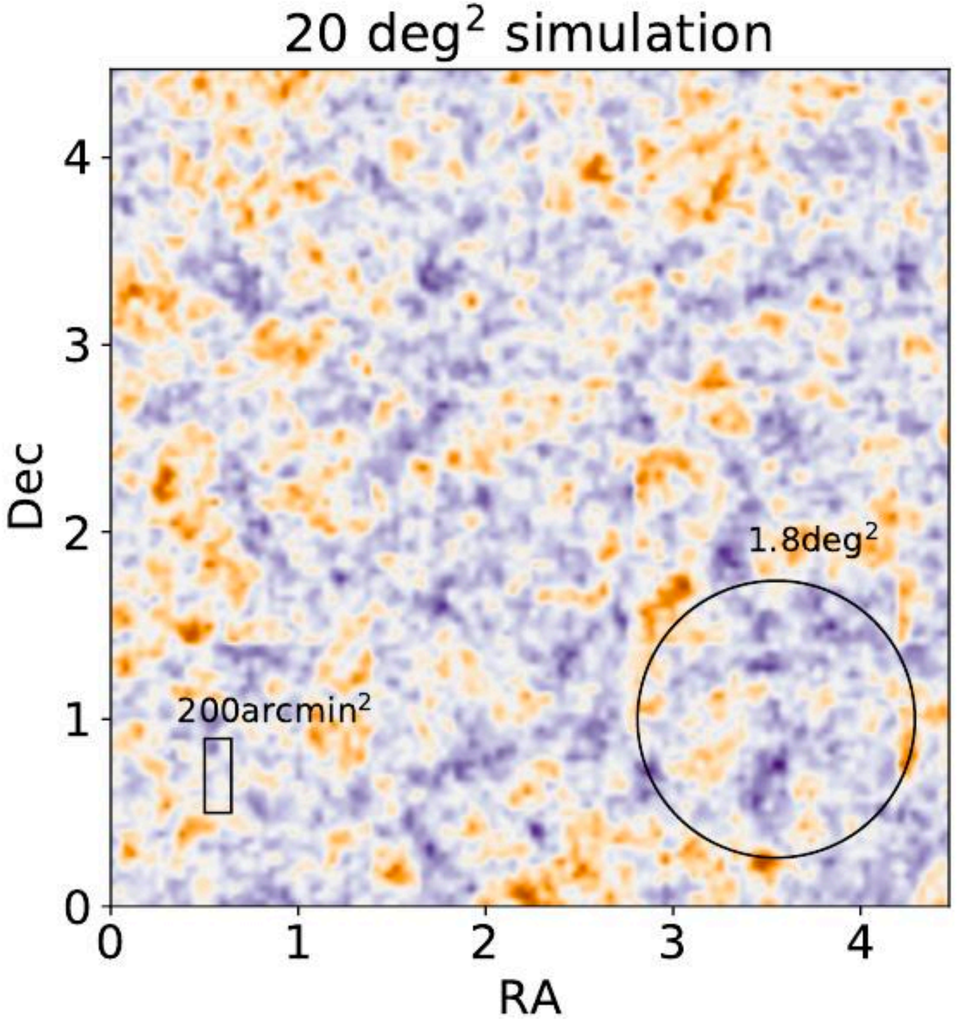
1. Trace the growth of $\mathrm{M}_\star$ across $3 < z < 7$ with ~500,000 galaxies

2. Investigate the galaxy-halo connection and evolution of SHMR across range of scales

3. Constrain the properties of dark energy using the non-linear power spectrum at high-*z*

4. Identify some of the earliest sites of galaxy formation and reionization + spectroscopically confirm

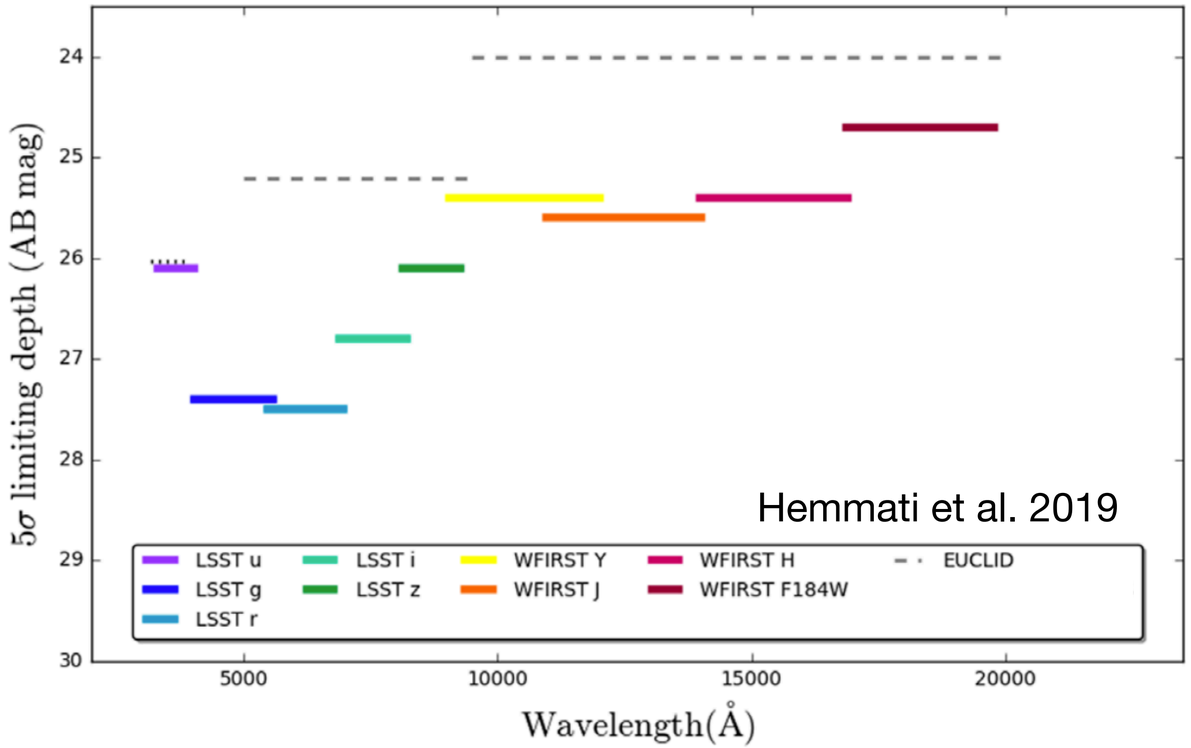
5. Locate and study the first galaxies to cease their star formation



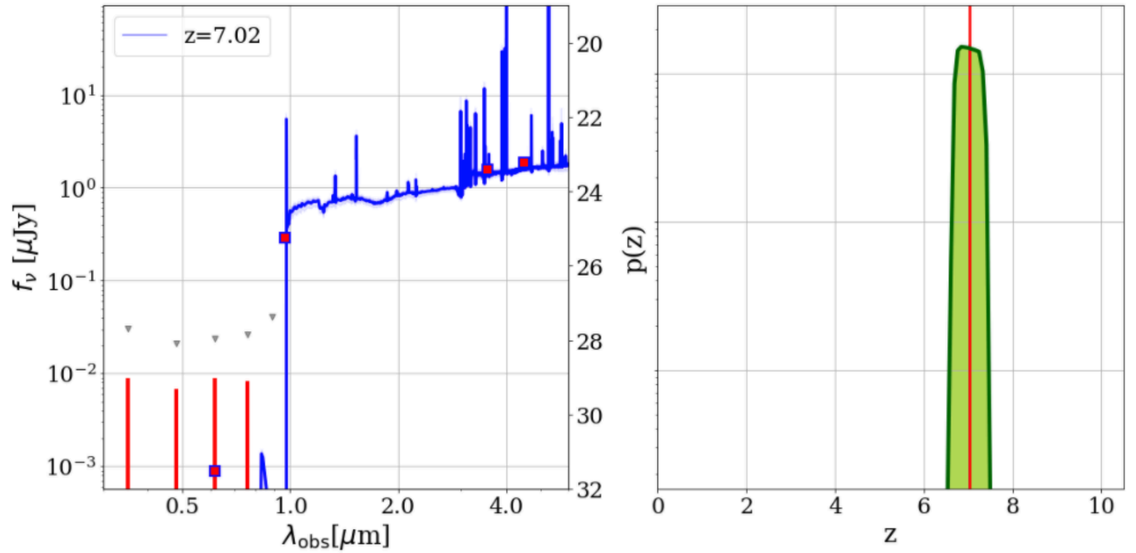
Synergy: H20 + Euclid/Roman

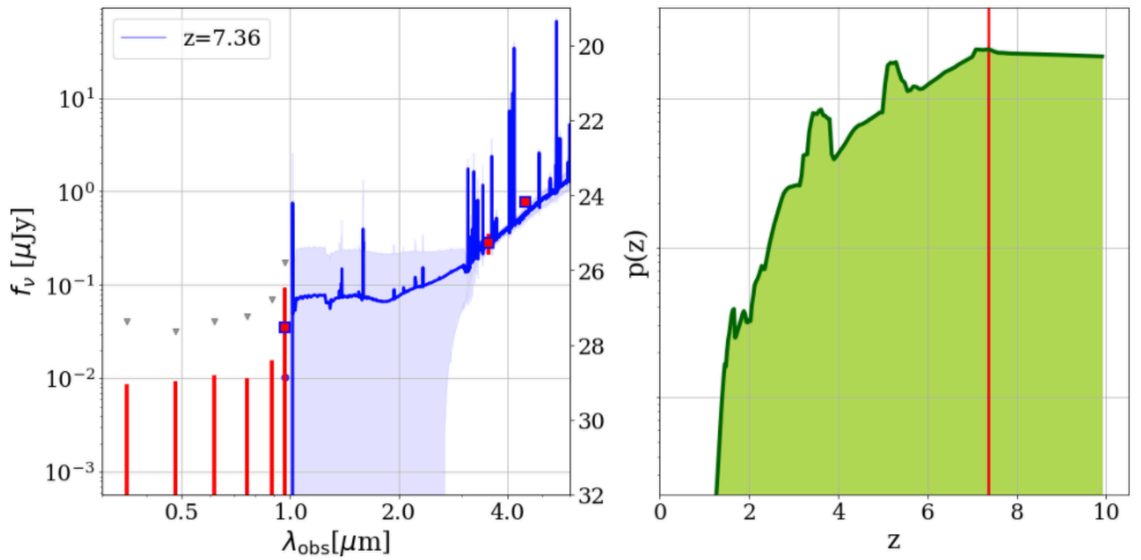
The need for NIR coverage: what does NIR photometry (uniquely) bring?

- NIR opens the $z > 7$ universe.



Hemmati et al. 2019





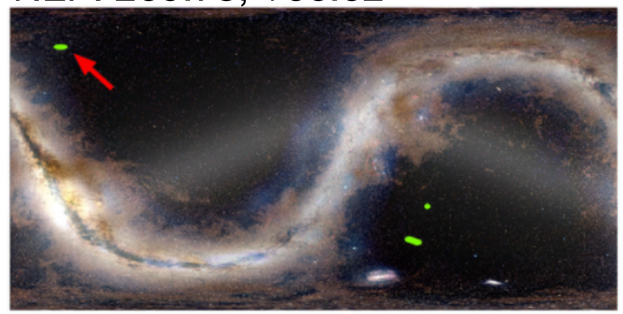
Synergy: H20 + Euclid

The H20 survey fields (NEP, EDFF) are the primary calibration fields for the Euclid mission, targeted by Deep Survey

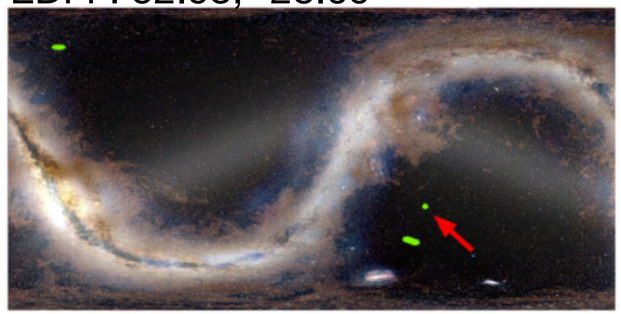
- 2 mags deeper than wide survey (AB mag ~ 26)

- “Blue” + “red” grism spectroscopy

NEP: 269.73, +66.02



EDFF: 52.93, -28.09



https://www.cosmos.esa.int/web/euclid/euclid-survey

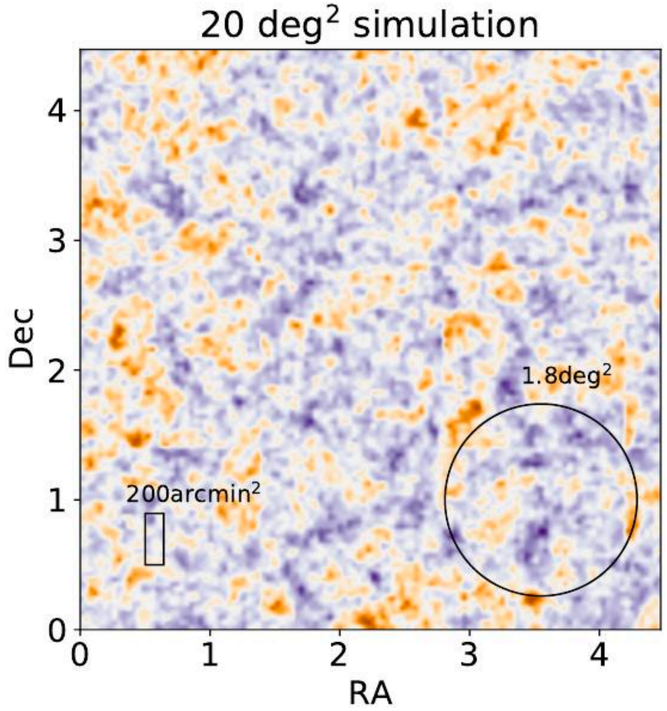
Table 1. Sampling and coverage information of the three fields of the *Euclid* Deep Survey (EDS).

Field Name	Area (deg^2)	Depth	Visits	Strategy	Additional information
EDS-north	10	nominal	40	30 visits to core 10 deg^2 (field visited with 2 consecutive passes) + 10 calibration visits (over 20 deg^2)	north ecliptic pole
EDS-south	20	nominal	40	30 visits (clustered every 6 months with 2 consecutive passes) + 10 calibration visits. All with 20 deg^2	south ecliptic pole
EDS-Fornax	10	nominal	56	7 visits in 7 days every 6 months. All with 10 deg^2	limited visibility in time

Inserra et al. 2018

Synergy: H20 + Euclid ≈ LSST + Roman

- The combination of Roman's High Latitude Survey (HLS) + Rubin's LSST will provide unmatched science
- However, high-*z* science will have to wait **~10 years**
- H20 allows high-*z* science years in advance & a view of LSST+Roman in miniature
  - ✓ Near equal depth in optical
  - ✓ Cosmologically significant volume



Filter	*u*	*g*	*r*	*i*	*z*	*Y*
H20 Mag. Limit (5σ)	26.2	27.5	27.5	27	26.5	26*
LSST Mag. Limit (5σ)	26.1	27.4	27.5	26.8	26.1	24.9

Synergy: H20 + Roman

Should Roman target NEP and/or EDFF with deep (AB mag ~ 28) survey?

NEP

1. In continuous viewing zone
2. Will be targeted by JWST (NEP Time-Domain Field)

EDFF

1. ~7 deg off from current continuous viewing zone
2. Contains CDFS/GOODS-S
3. Accessible with ALMA

Both

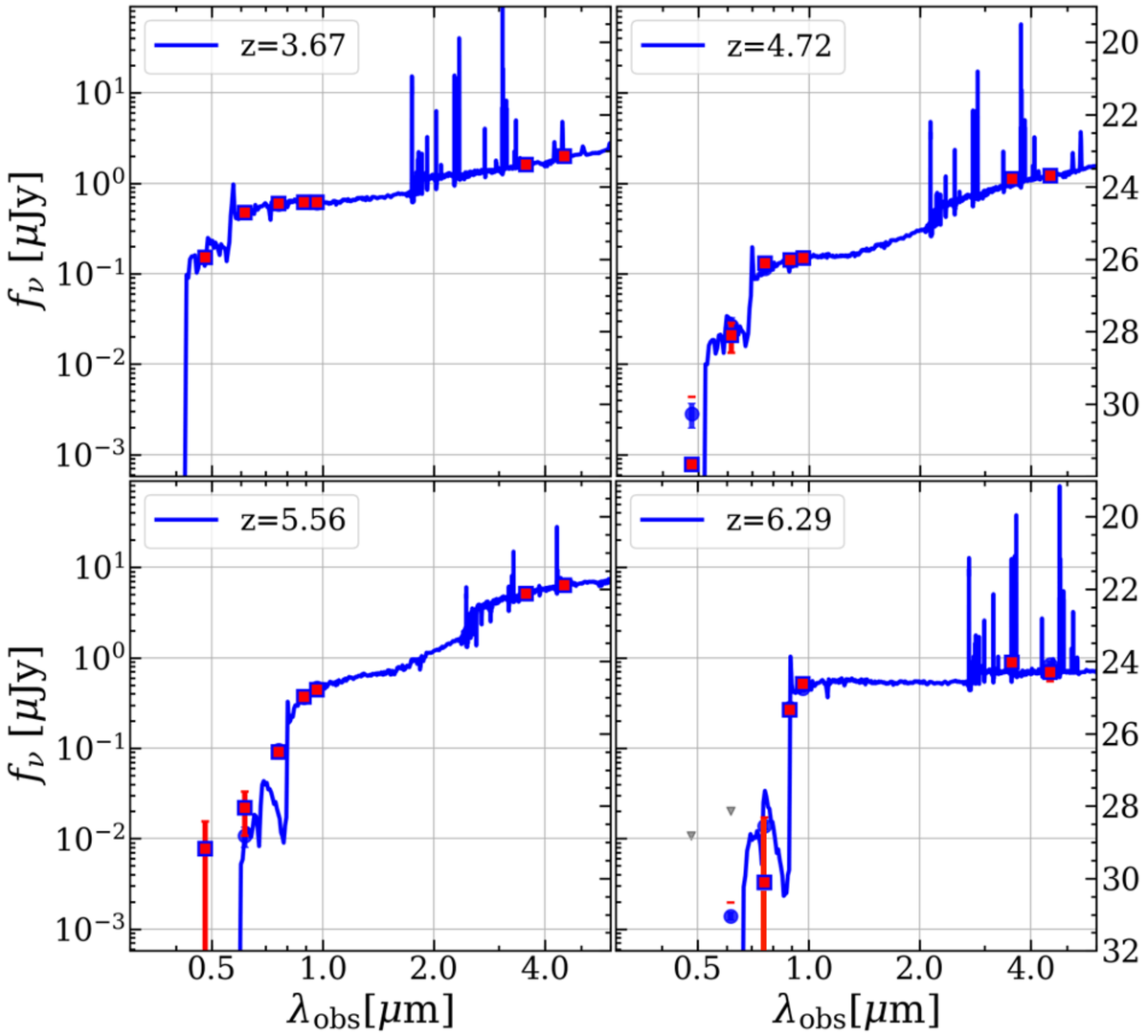
- Targeted by Euclid: repeat visits for SN science, add depth, spectroscopy
- Large contiguous area covered by **deep Spitzer** + HSC, enabling unique cosmological probes to high-*z*

Looking Ahead: Photometric Redshifts

All extragalactic science utilizing H20 (and or LSST/Euclid/Roman) data will be contingent on *high-quality* photometric redshifts

For a *realistic* test, use **COSMOS2020** catalog (Weaver, Kauffman et al. in prep) and investigate several scenarios:

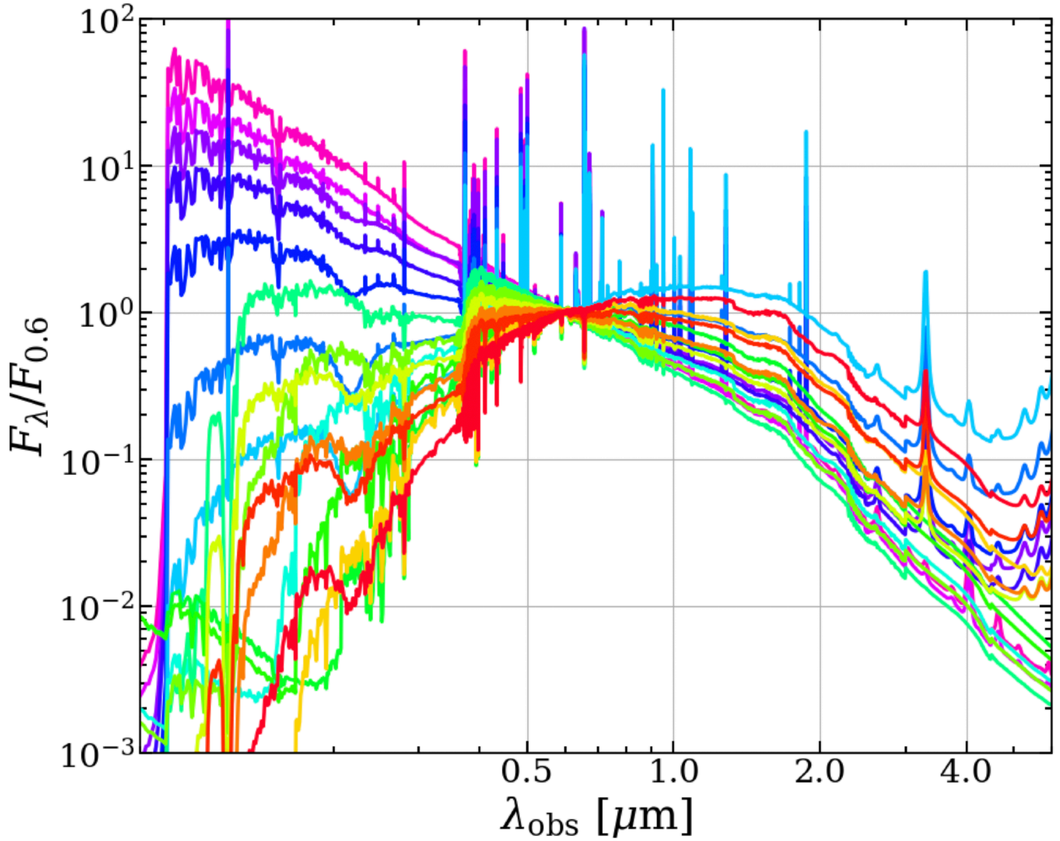
1. **HSC-only**: *grizy*
2. **H20**: *ugrizy*, [3.6μm], [4.5μm]
3. **H20+Euclid (or Roman)**: *ugrizy*, YJH, [3.6μm], [4.5μm]



Looking Ahead: Photometric Redshifts

Method:

- EAZY-py (github.com/gbrammer/eazy-py; Brammer et al. 2008)
- 16 FSPS synthetic templates, with combinations allowed
- Templates evolve with redshift, altering ionization & line strengths
- *Not* calibrated on spectroscopic redshift sample
  - Calibrations are performed “blindly” on random subset of catalog



Many more resources for photo-z investigation:

Hemmati et al. (2019), Laigle et al. (2019), Graham et al. (2018, 2020), Euclid Collaboration (2020), Lee & Chary (2020)

Looking Ahead: Photometric Redshifts

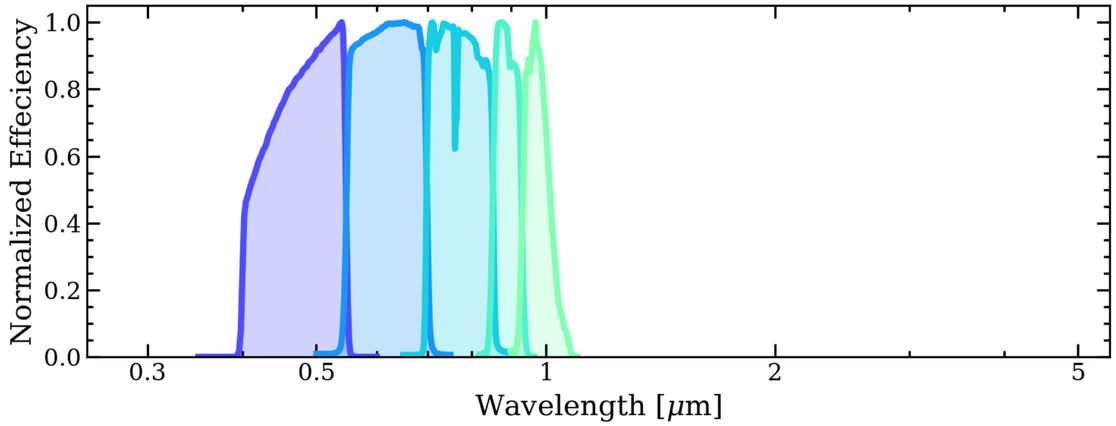
Results HSC only (e.g., Subaru SSP)

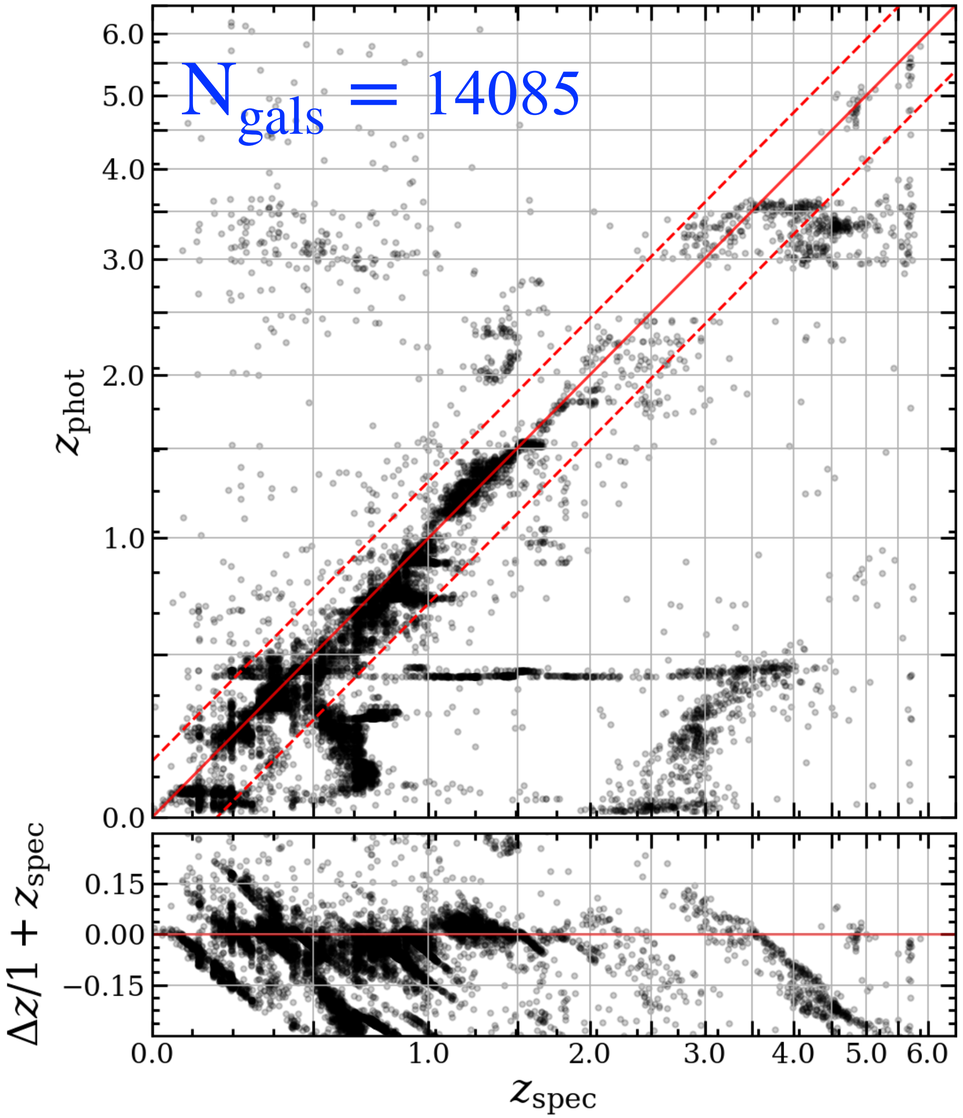
- Spectral coverage: *grizy*

$$\sigma_{\Delta z/1+z} = 0.086$$

$$\eta_{\text{outlier}} = 34.0\%$$

- Huge uncertainty at $z > 2$





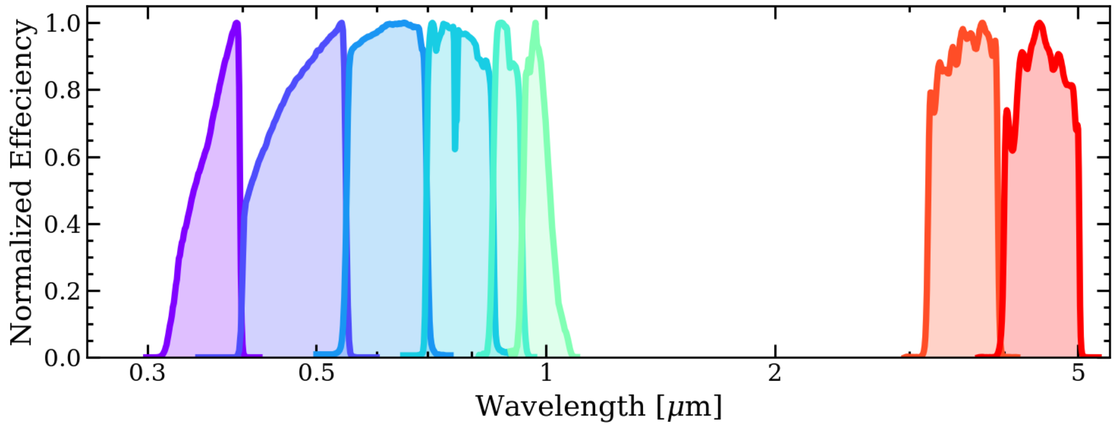
Looking Ahead: Photometric Redshifts

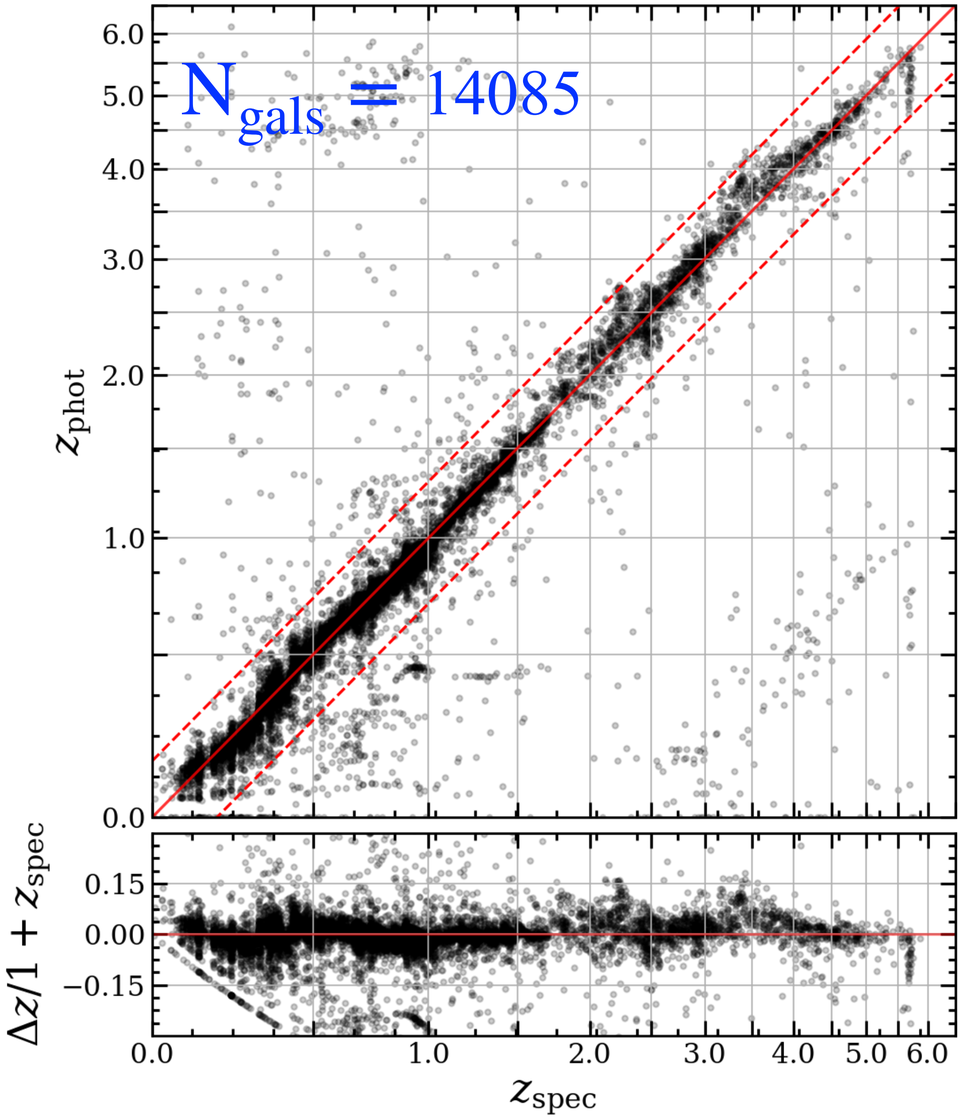
Results Hawaii Two-0 filter set

- Spectral coverage: *ugrizy*, [3.6μm], [4.5μm]

$$\sigma_{\Delta z/1+z} = 0.027$$

$$\eta_{\text{outlier}} = 6.86\%$$





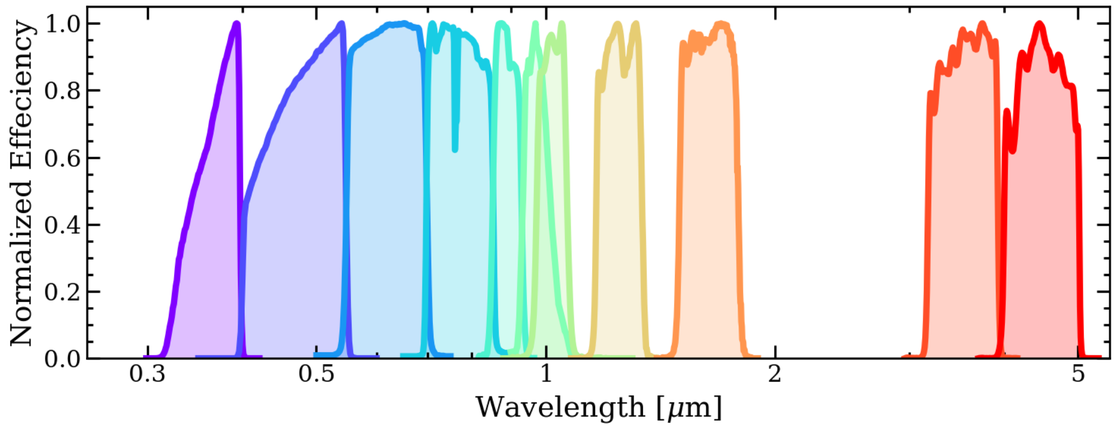
Looking Ahead: Photometric Redshifts

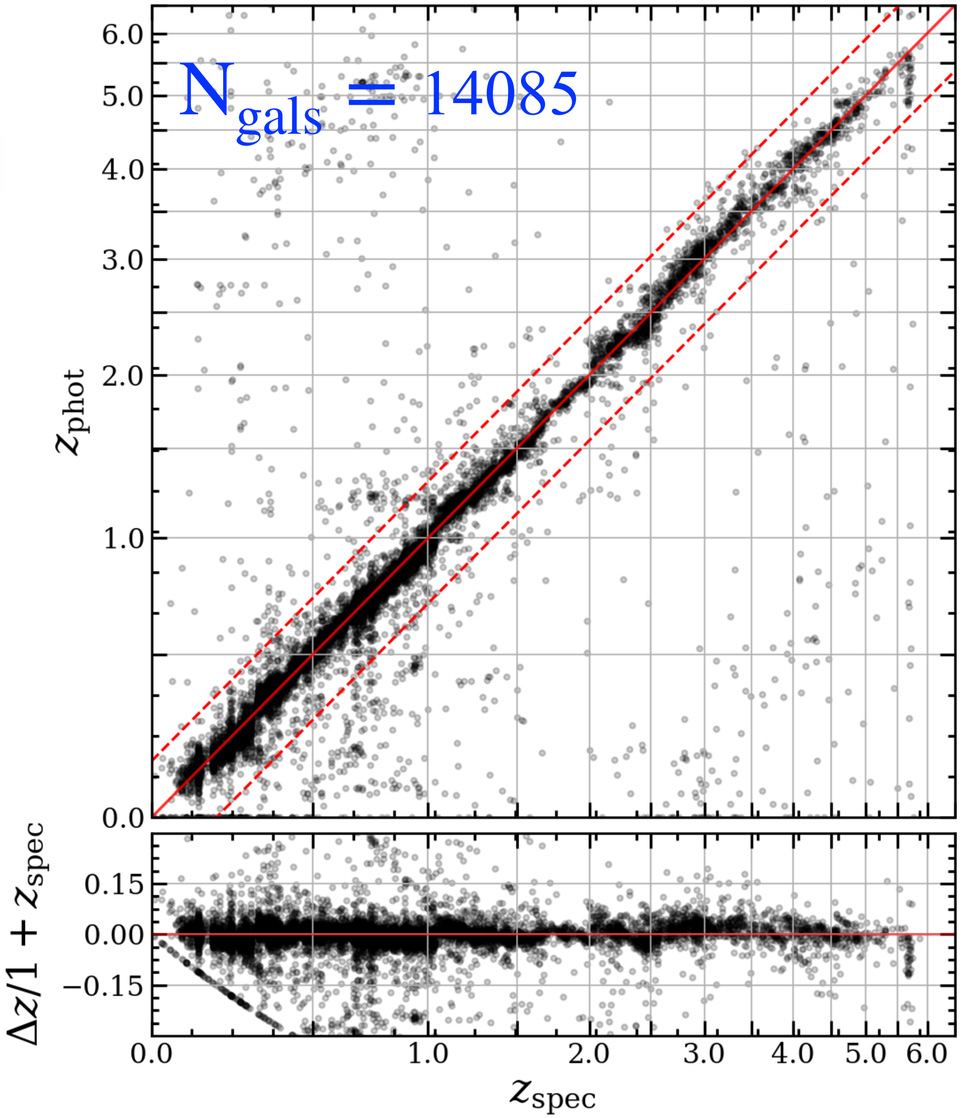
Results Hawaii Two-0 + Euclid/Roman

- Spectral coverage: *ugrizy*, YJH, [3.6μm], [4.5μm]

$$\sigma_{\Delta z/1+z} = 0.022$$

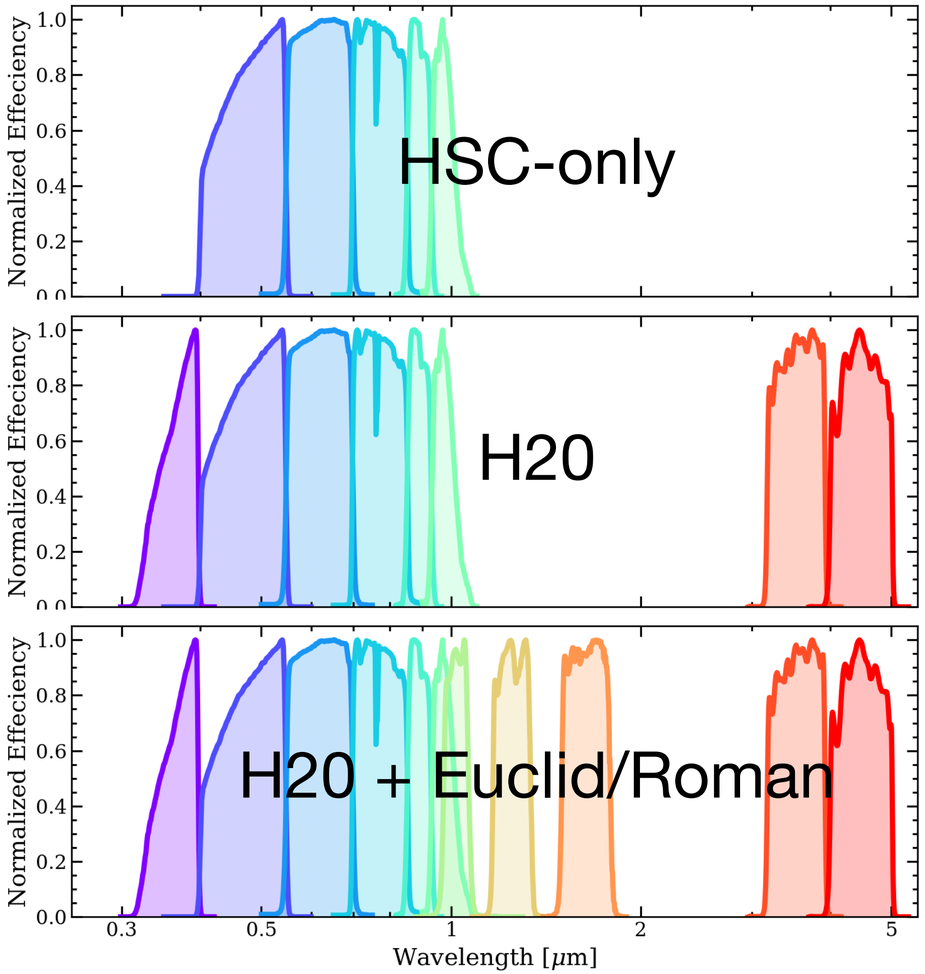
$$\eta_{\text{outlier}} = 6.40\%$$





Looking Ahead: Photometric Redshifts

Photo-z summary



$N_{gals} = 14805$		$N_{gals} = 13450$		$N_{gals} = 1355$	
$\eta_{outlier}$ All	$\sigma_{\Delta z/1+z}$ All	$\eta_{outlier}$ $z < 2.5$	$\sigma_{\Delta z/1+z}$ $z < 2.5$	$\eta_{outlier}$ $z > 2.5$	$\sigma_{\Delta z/1+z}$ $z > 2.5$
34.0%	0.086	29.4%	0.424	80.1%	0.424
6.86%	0.027	6.1%	0.026	14.2%	0.04
6.40%	0.022	5.7%	0.020	12.8%	0.036

$z < 6.5$

Hawaii Two-0 Data Products

Current:

- Sky viewer:
  - Color and BW images of our survey fields - https://h20.ifa.hawaii.edu/
- Publications in prep:
  - Survey overview, description of observations (McPartland et al.)
  - Methodology, photometry, photo-*z* (Zalesky et al.)
  - ML techniques to predict galaxy colors (Chartab-Soltani et al.)

Future:

- Catalog release ~ 2022; 10 million galaxies, 20 square degrees
- Image mosaics publicly available ~ 2023

Summary

1. The Hawaii Two-0 (H20) twenty square degree survey:
   - NEP + EDFF to a depth of AB < 27.5; *ugrizy*, [3.6μm], [4.5μm]
2. Opportunities for synergy between Hawaii Two-0 & upcoming missions:
   - Euclid ✓, JWST ✓, Roman…?
   - H20 obtains excellent photo-*z*, improves with NIR (esp. high-*z*)
3. Hawaii Two-0 data products:
   - Sky viewer, 3 publications in prep., catalogs 2022, images 2023

Synergy: Photometry

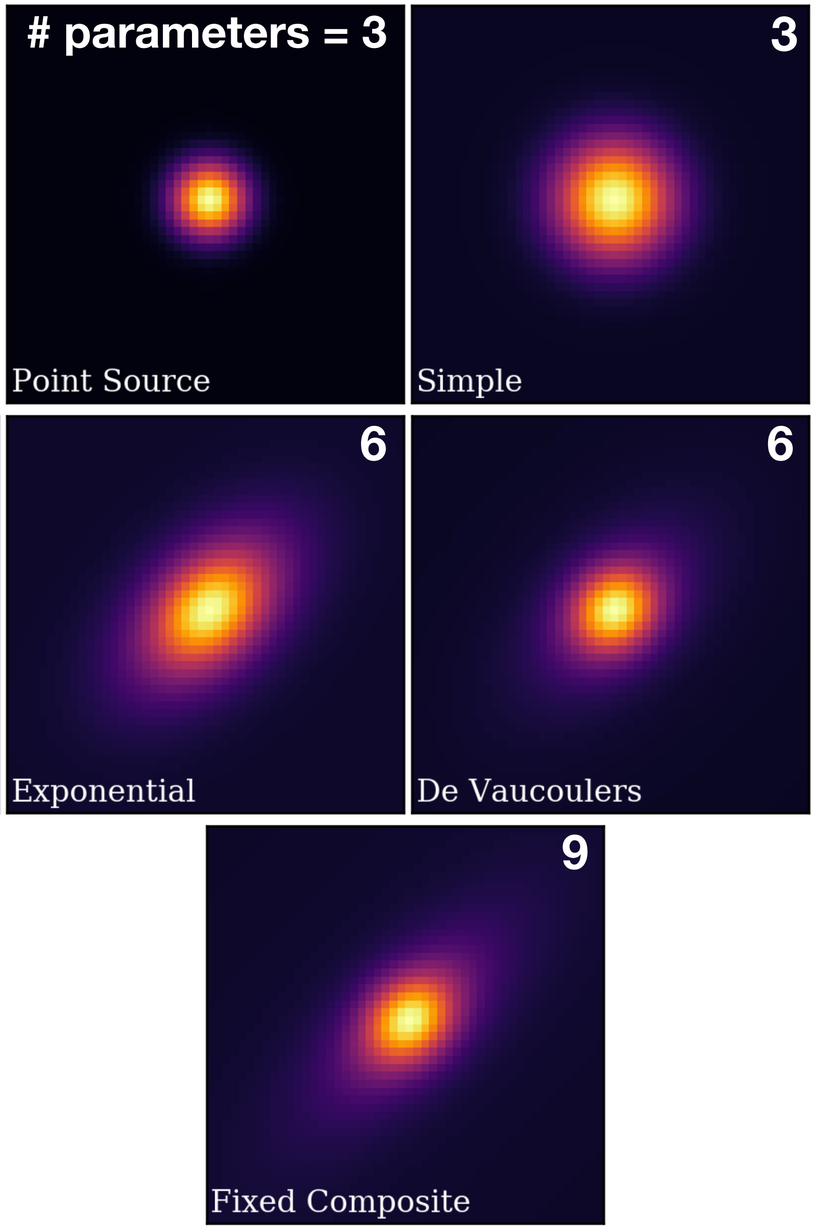
Photometry tools built for next generation missions:
The Farmer (Weaver, Zalesky, et al. in prep)

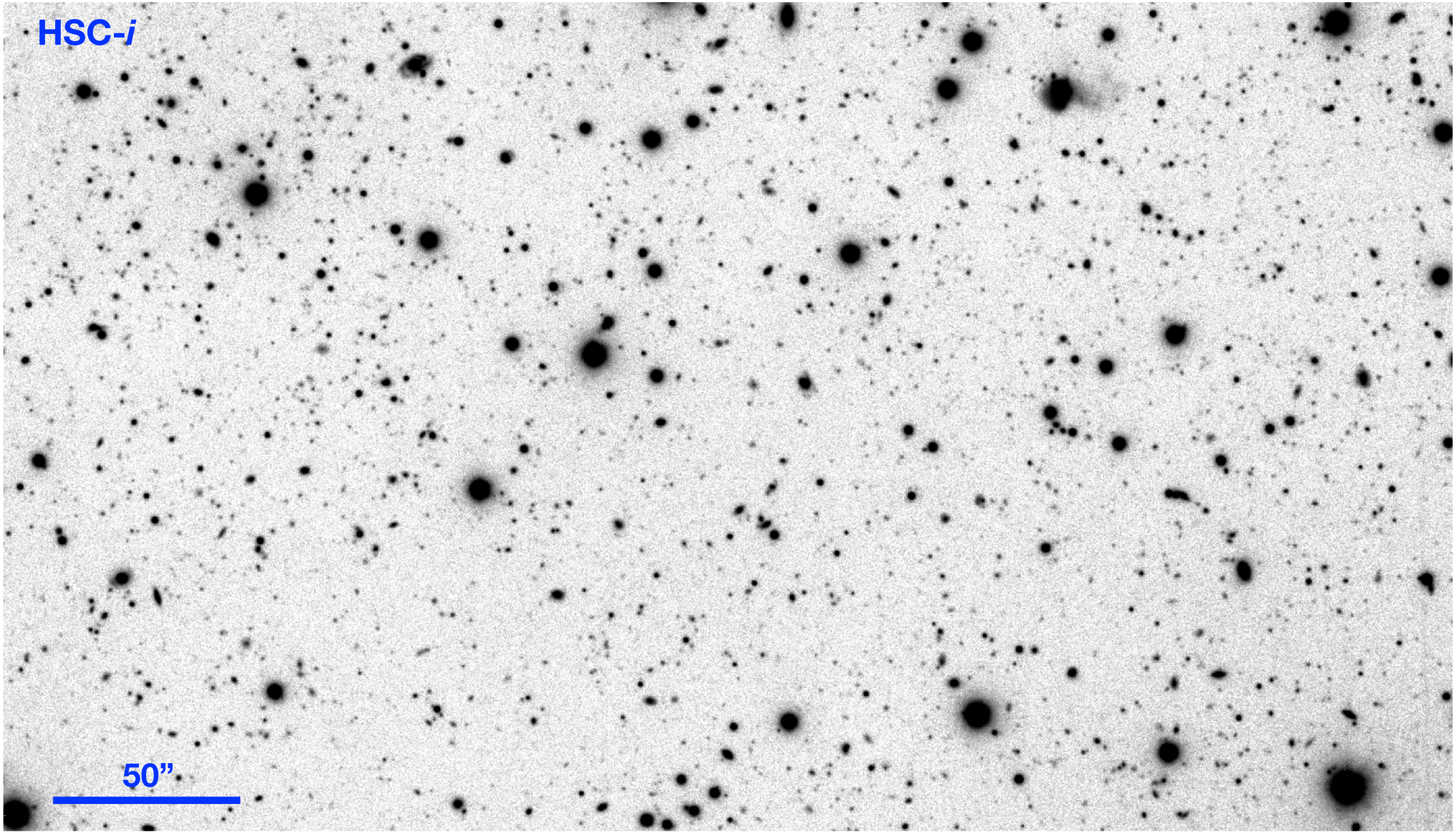
- The Farmer utilizes **The Tractor** (Lang & Hogg 2016)
- Detection performed on multi-wavelength coadd

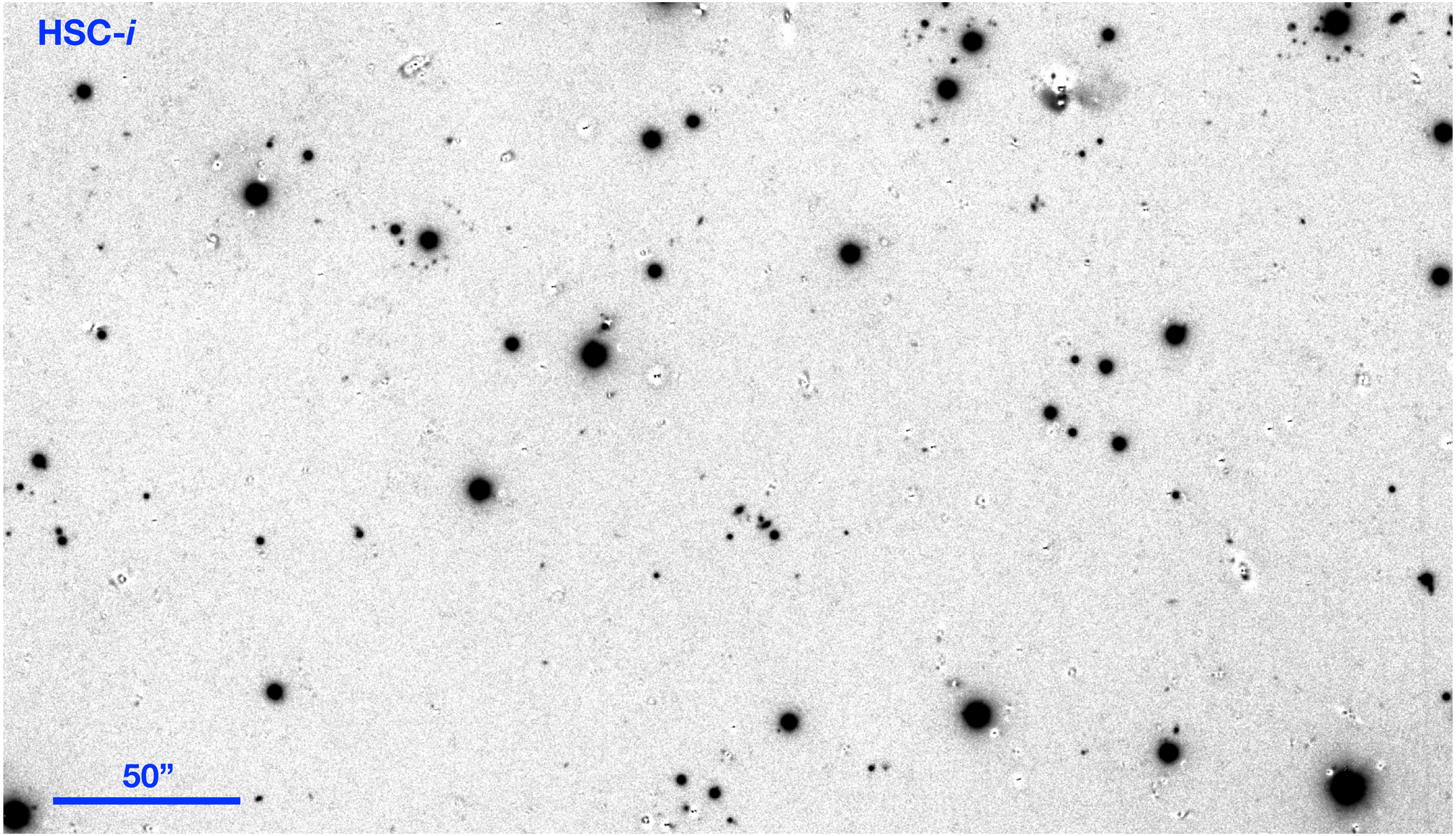
✓ Easily incorporate NIR images to detect high-z sources (e.g., COSMOS)

- Every source realized by a model with N > 3 free parameters
- Model structural parameters frozen, then flux optimized for each band *individually*

✓ Can force models on to lower resolution images or add additional imaging for self-consistent selection




HSC-*i*
50”

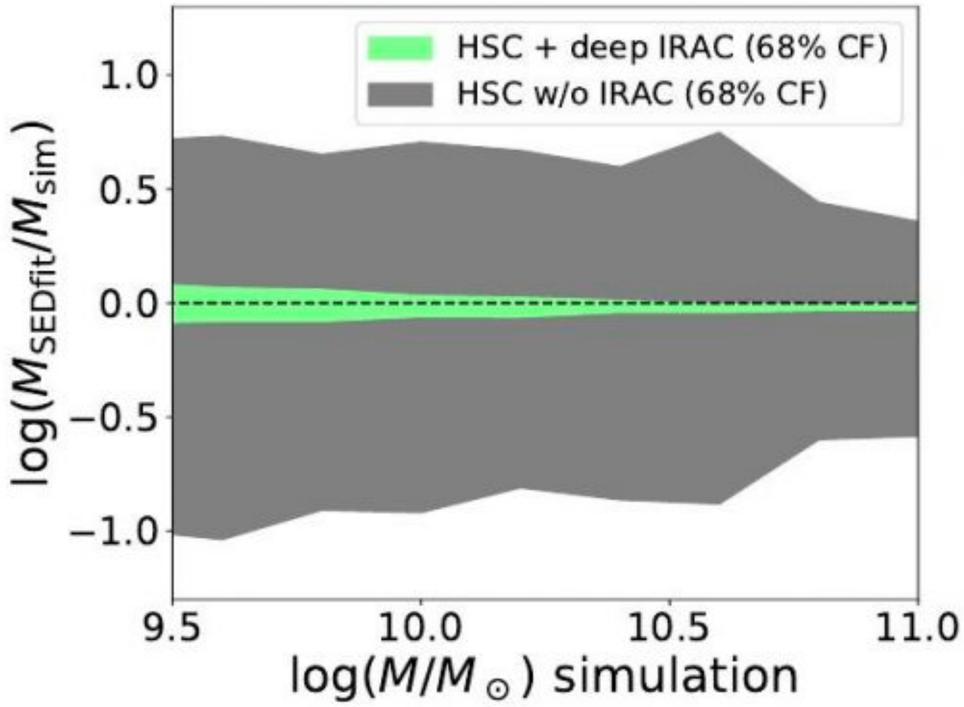

HSC-*i*
50”

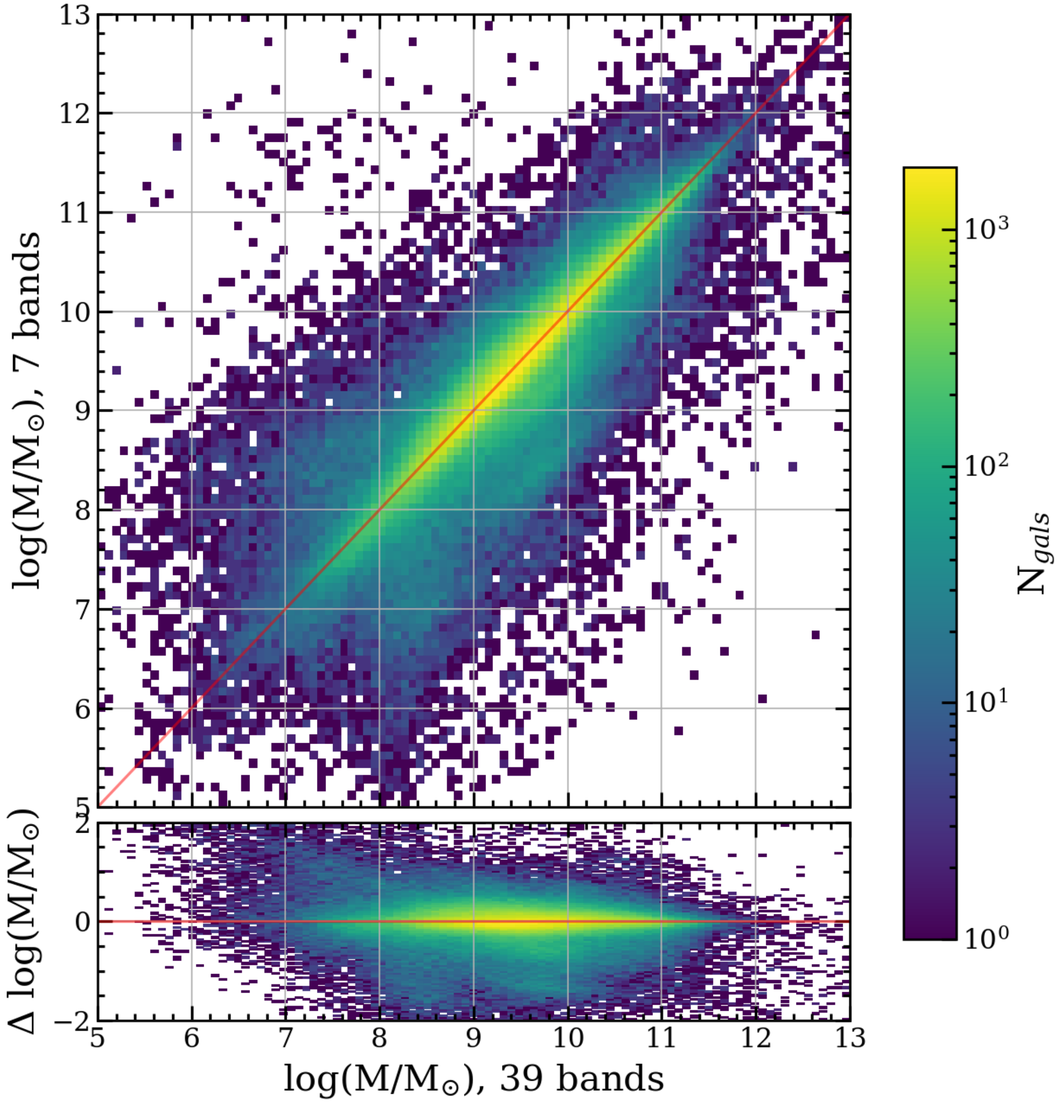
Appendix: COSMOS Stellar Mass Recovery

Results

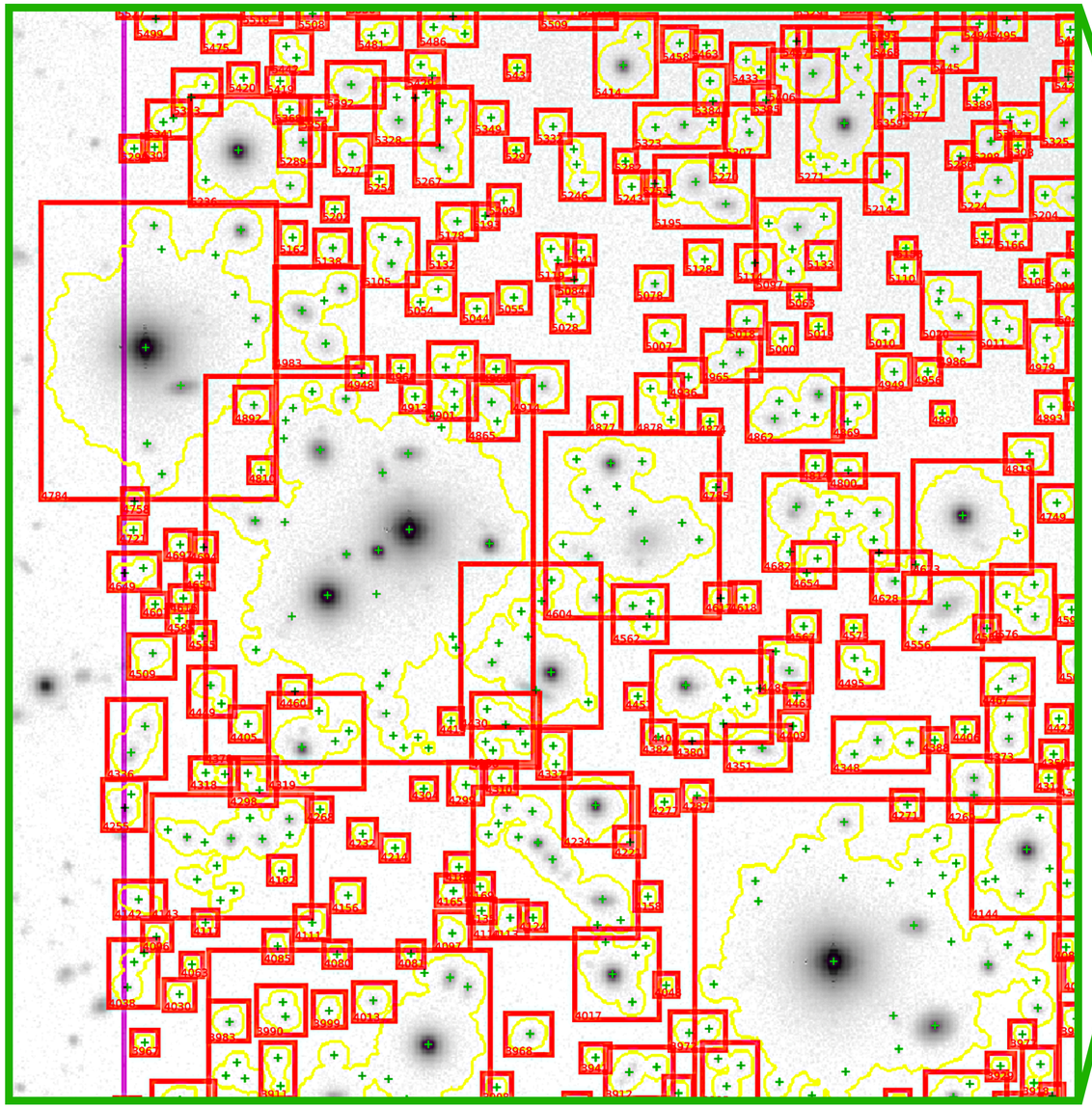
- Sample of photometric (high S/N) galaxies

- $\sigma \sim 0.2$ dex

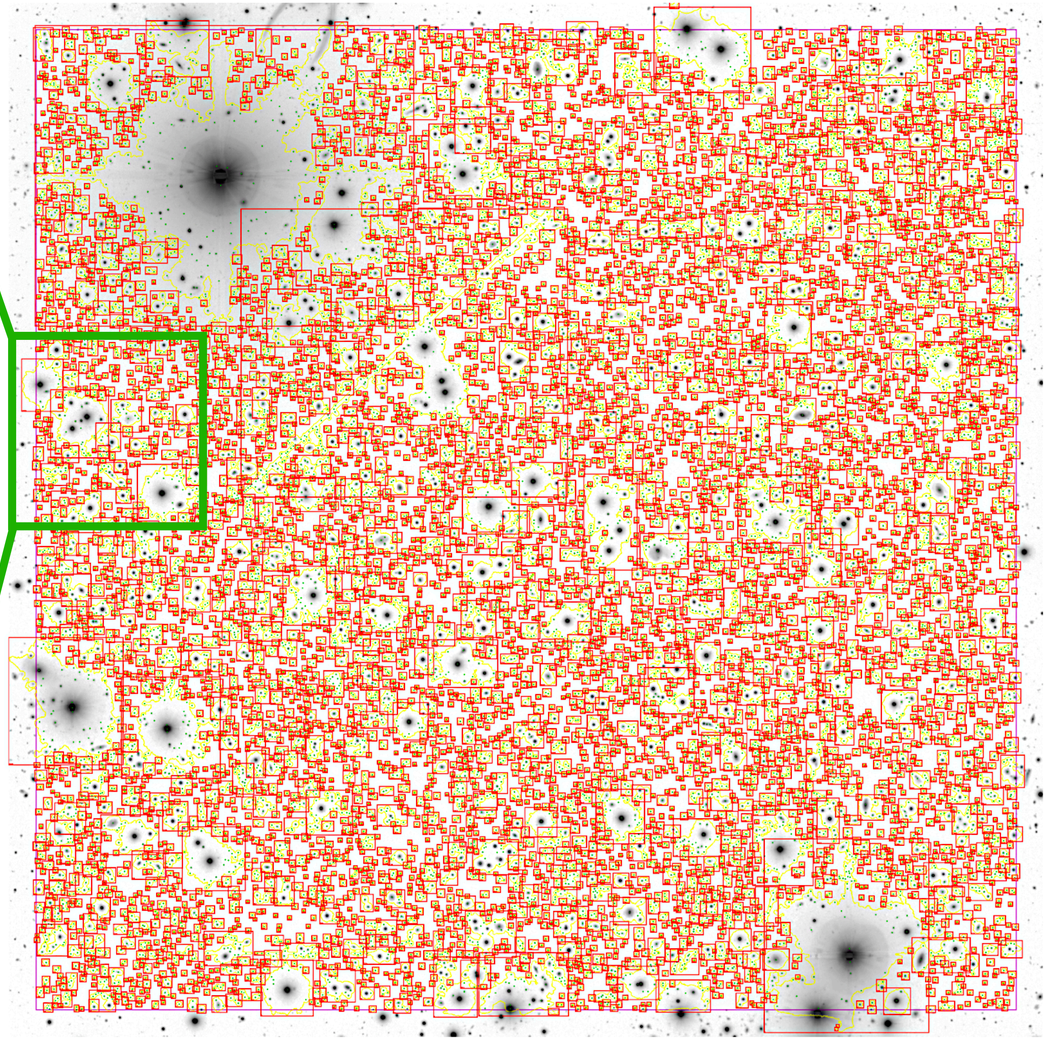




Appendix: Data Management

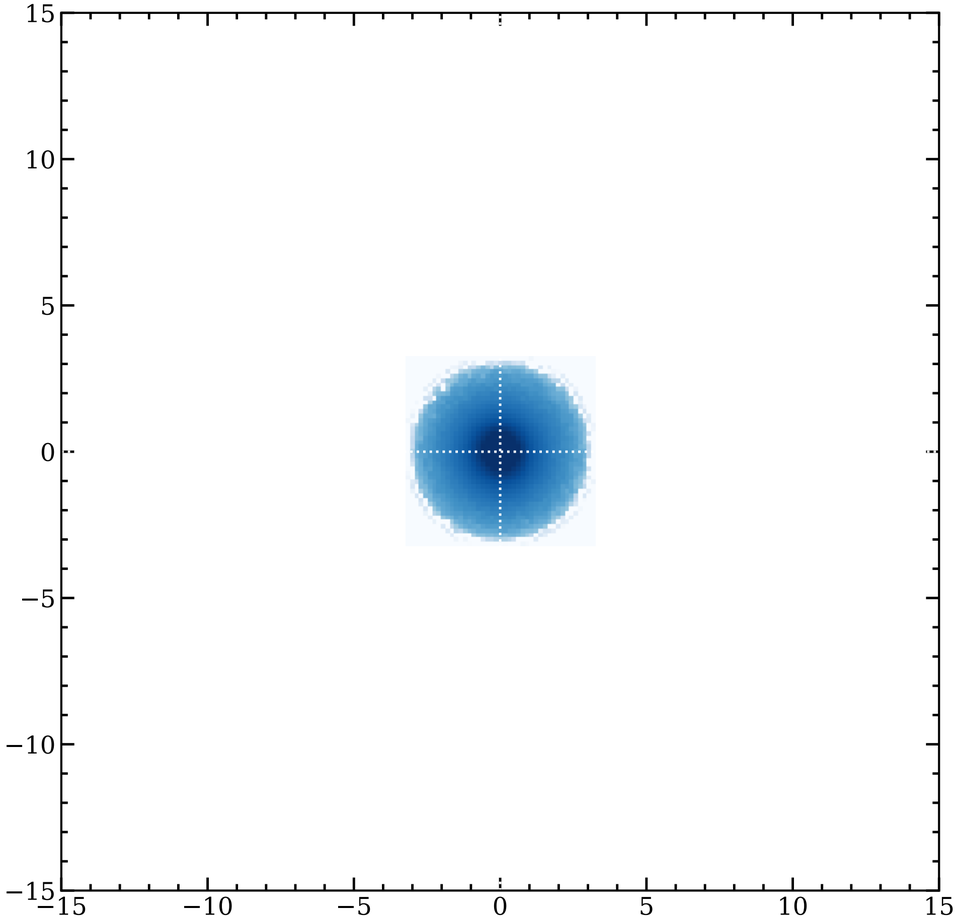


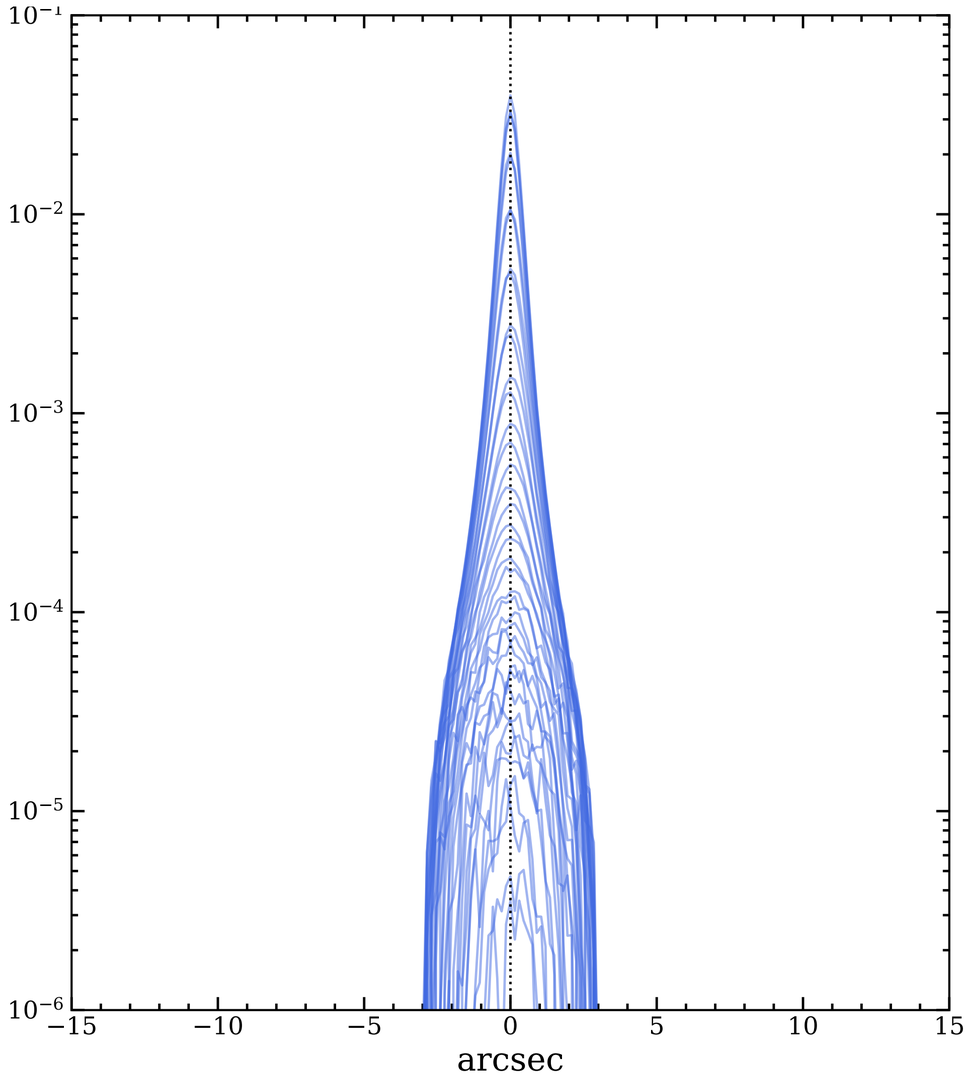
Brick = 1/100 of mosaic



Appendix: Selecting PSF

HSC-*i*





Appendix: Selecting PSF

IRAC [3.6μm]