Joint processing of LSST optical and VISTA near infrared imaging data

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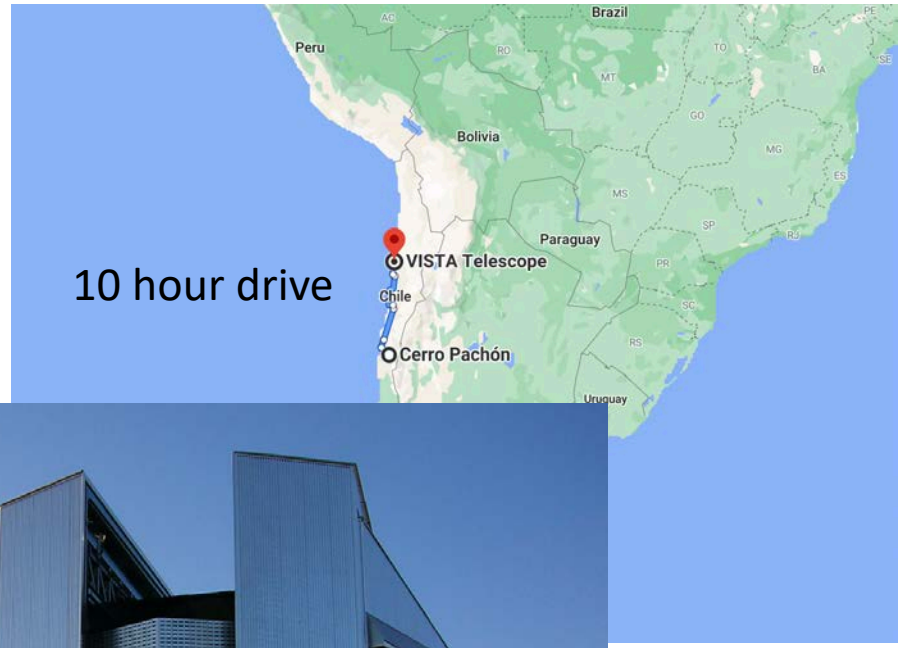
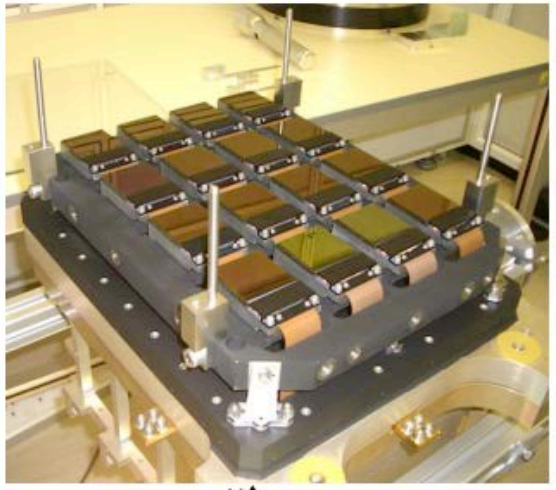
VISTA (Visible and Infrared Survey Telescope for Astronomy)

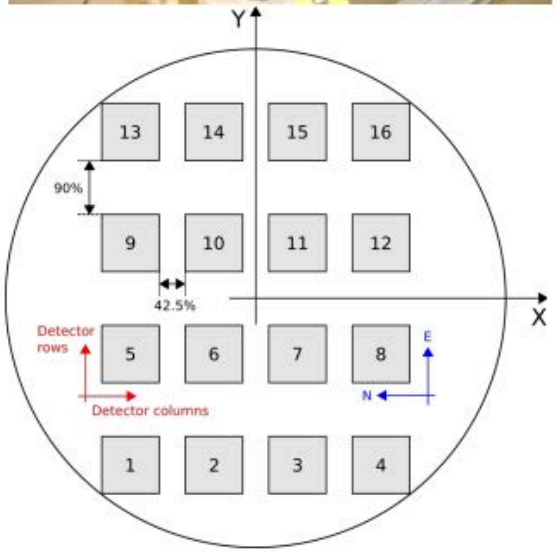
- 4-m class
- 0.339 arcsec pixels
- 1.65 deg^2 field of view
- Z,Y,J,H,Ks and narrow filters
- Point spread function full width at half maximum ~0.51 arcsec

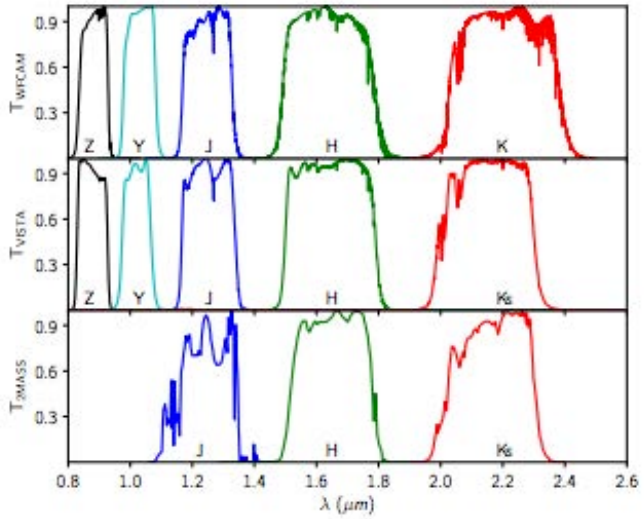


VIRCAM (VISTA InfraRed CAMera)

- JHKs key additional value filters
- Adds key near infrared coverage



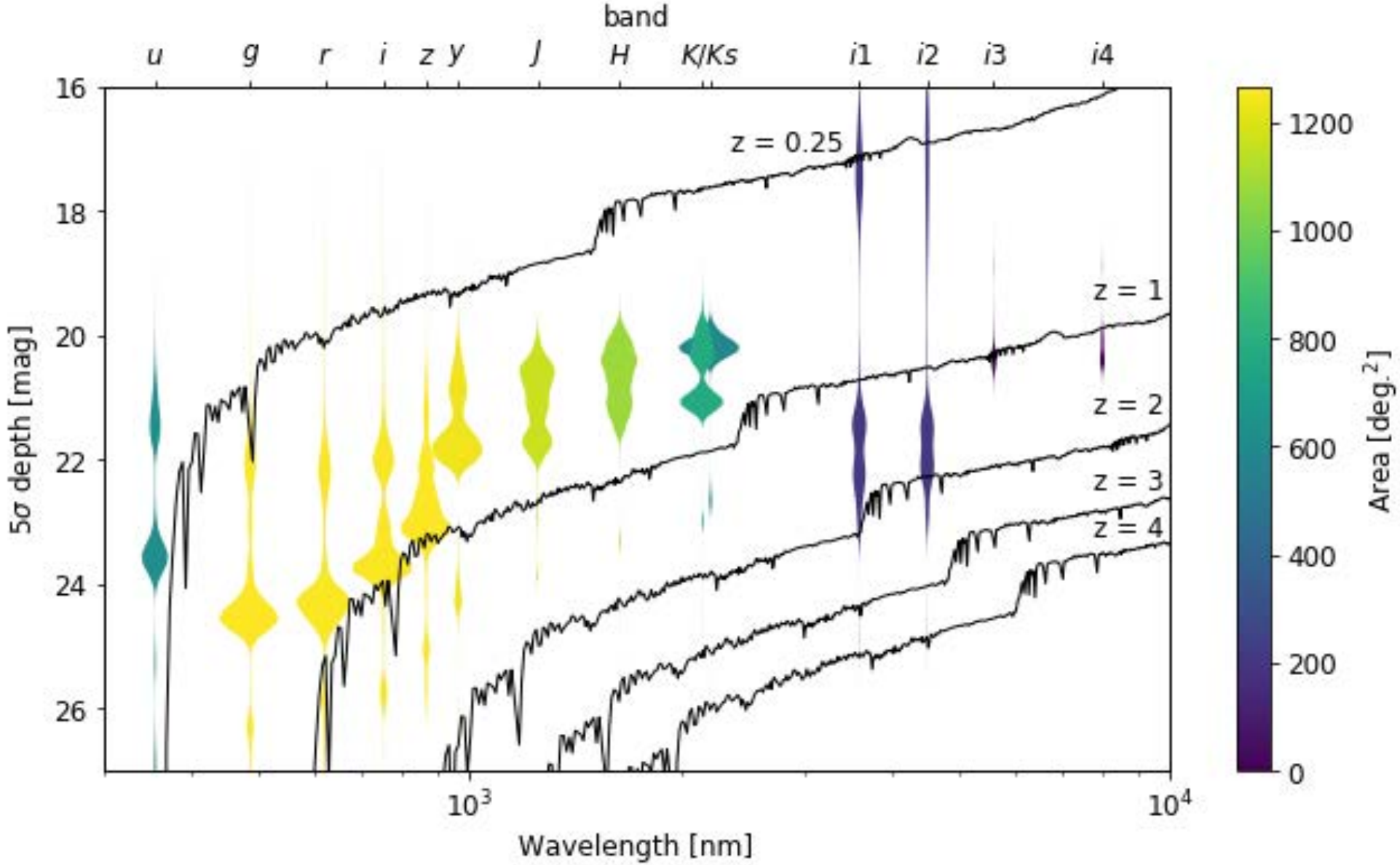




González-Fernández et al. 2015

Depth distributions on deep *Herschel* fields

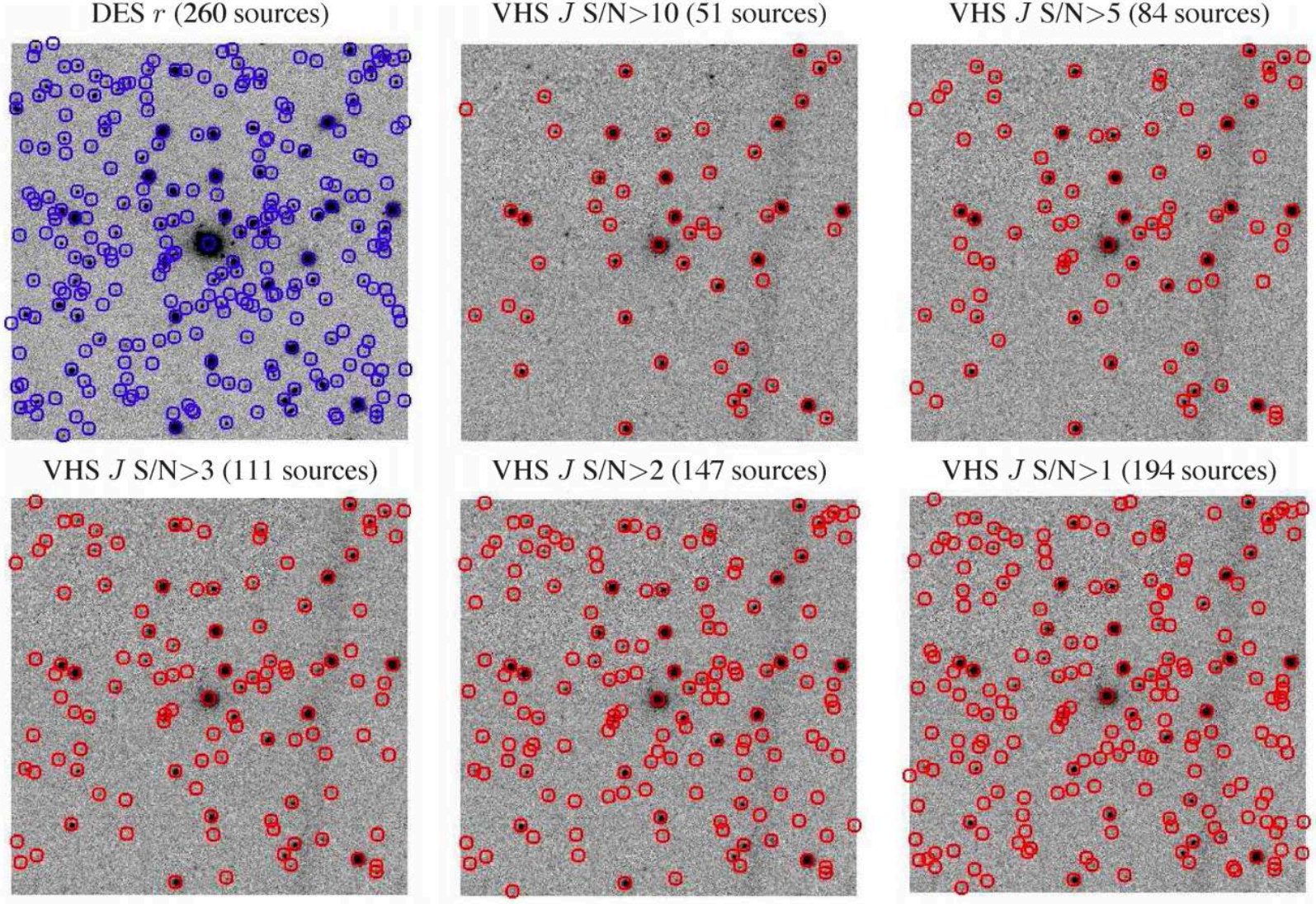
- *ugrizy* depths will come down
- This is showing the deep *Herschel* fields
- Rubin coverage will be dominated by VHS.



Shirley et al. 2019

Many low s/n VISTA sources are real

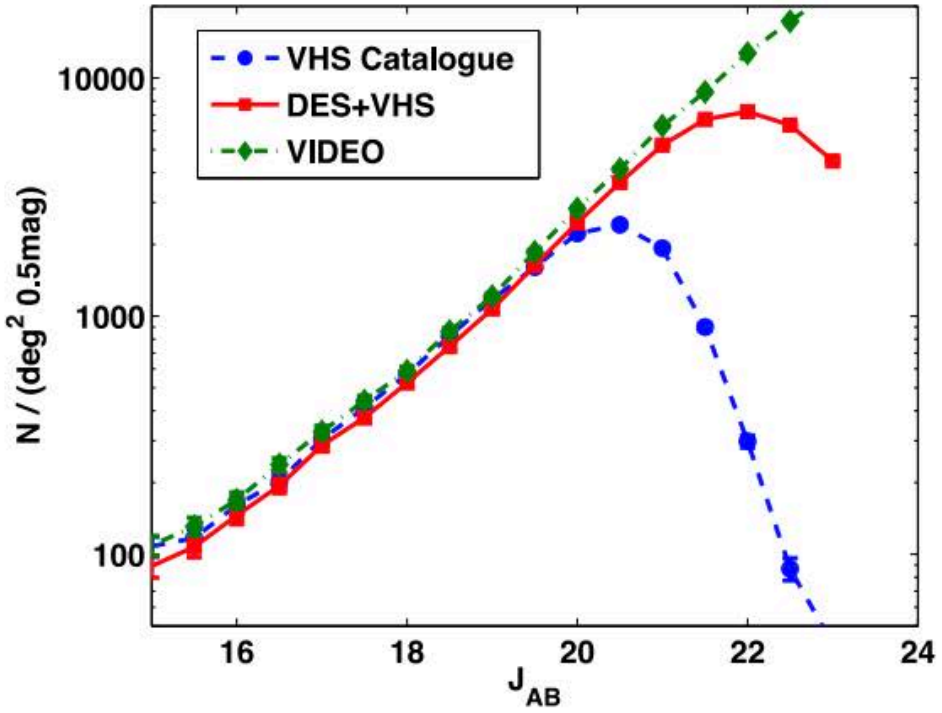
- Can be confident objects are not artifacts from other bands.
- Multiple low S/N measurements still have constraining power.

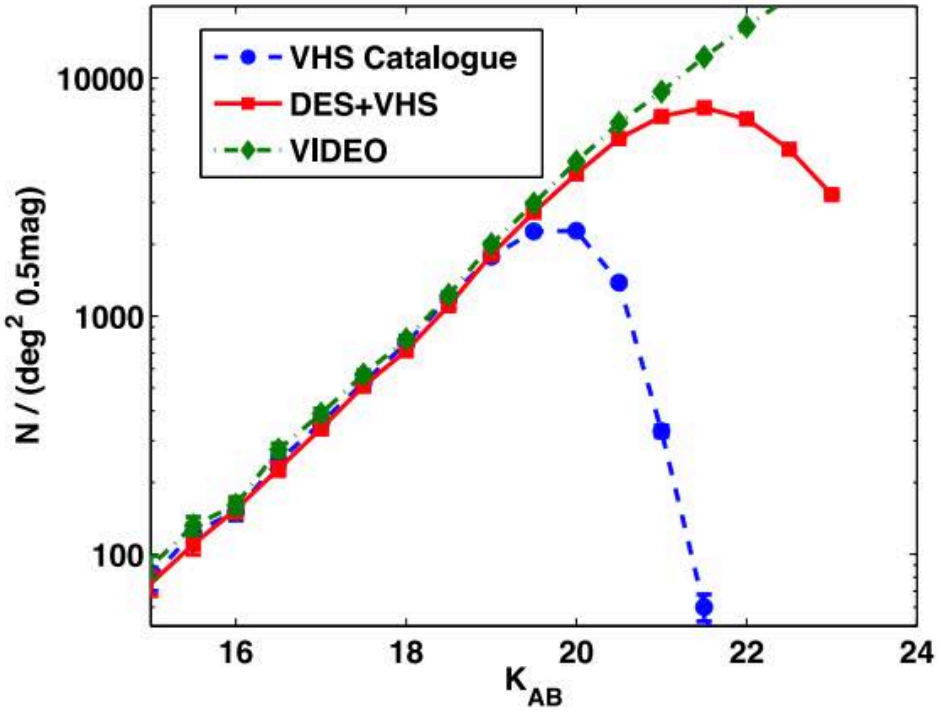


Banerji et al. 2015

Harnessing optical depth to drive low s/n numbers

- Confirming method can increase ‘effective depth’.
- Still interesting objects in the VISTA data.

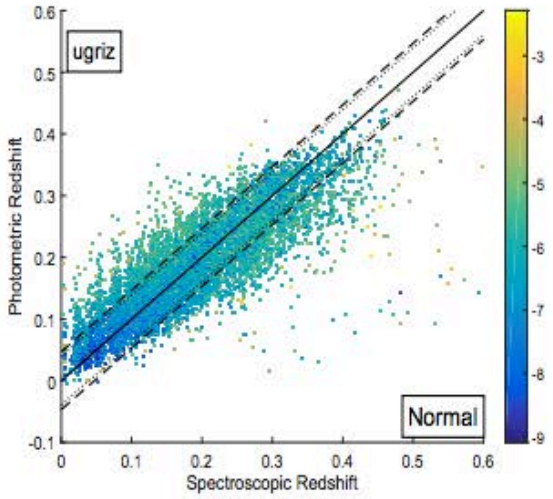


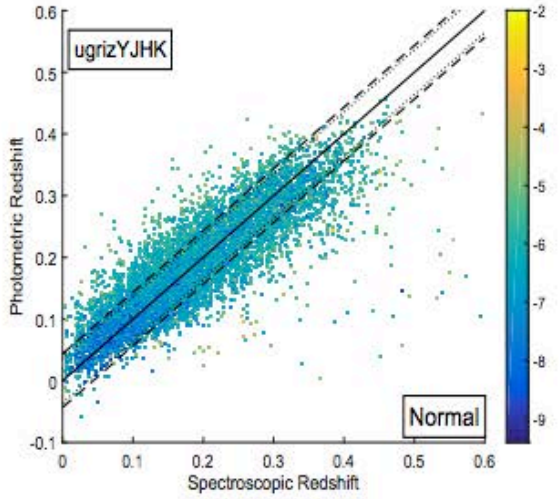


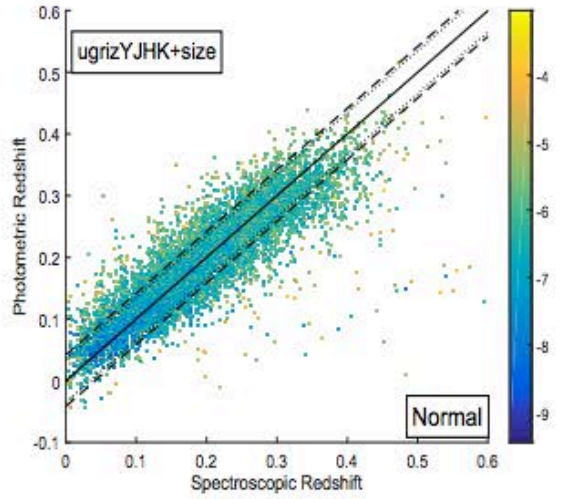
Banerji et al. 2015

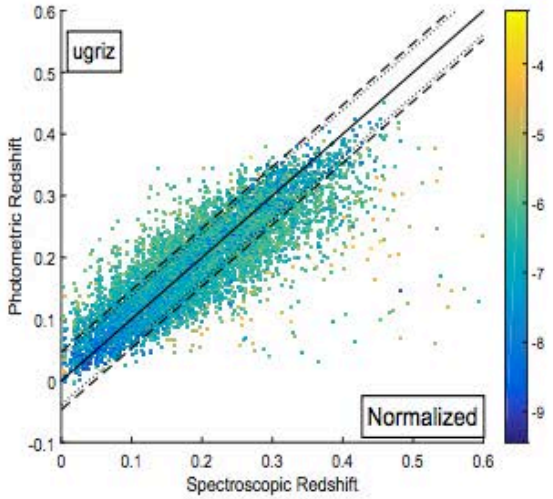
JHKs contribute to photo-z accuracy

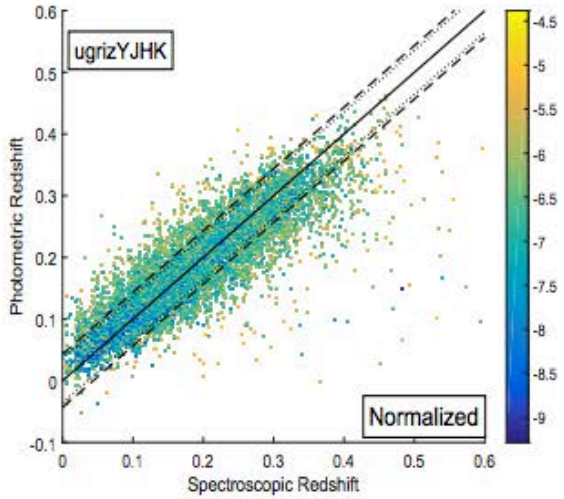
- Impact of JHKs on photo-z
- Investigating how constraining power depends on depth

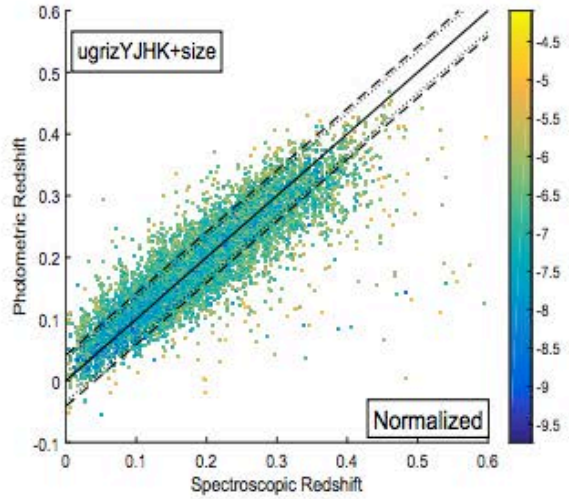








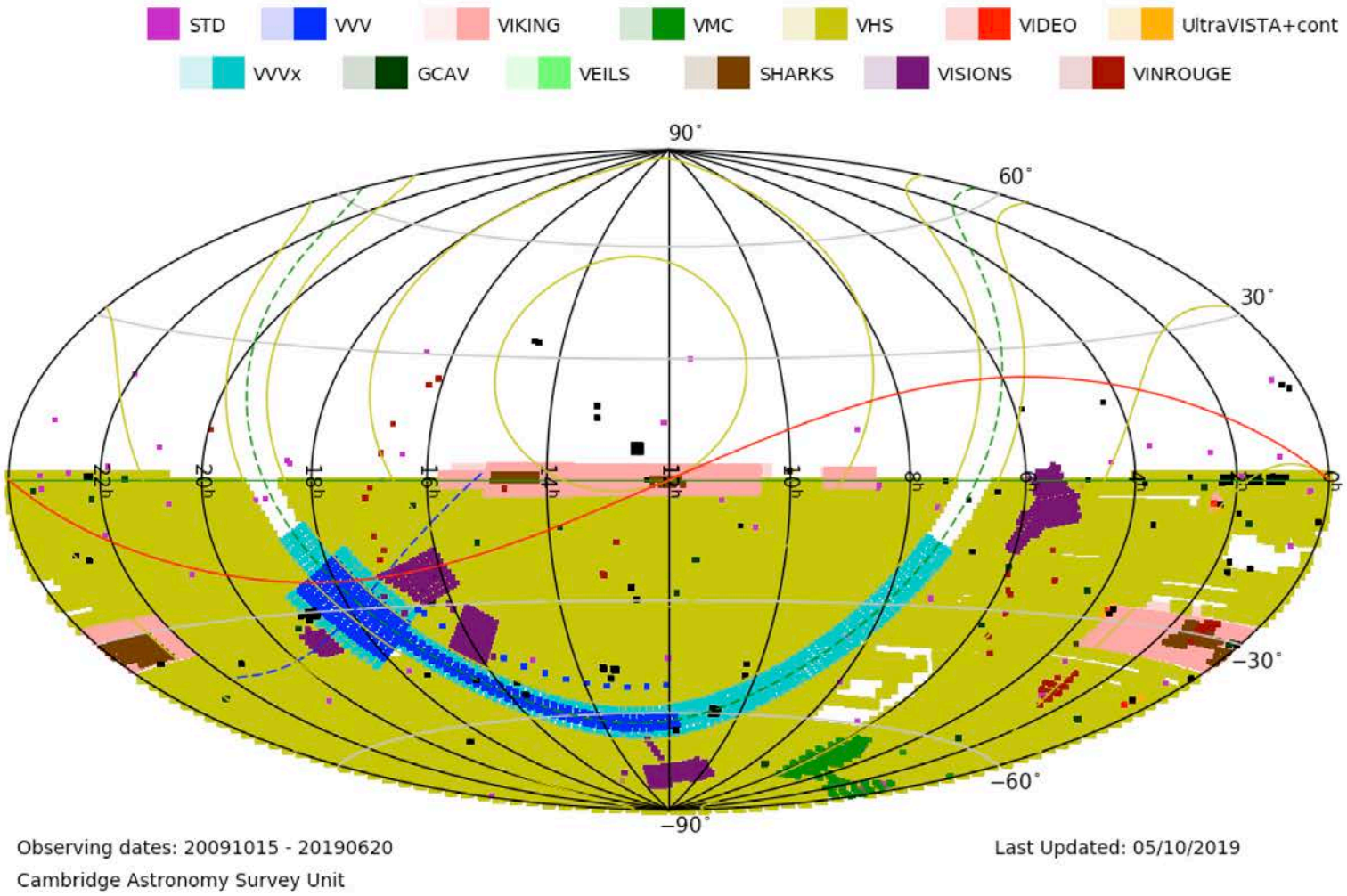




Gomes et al. 2017

VISTA surveys

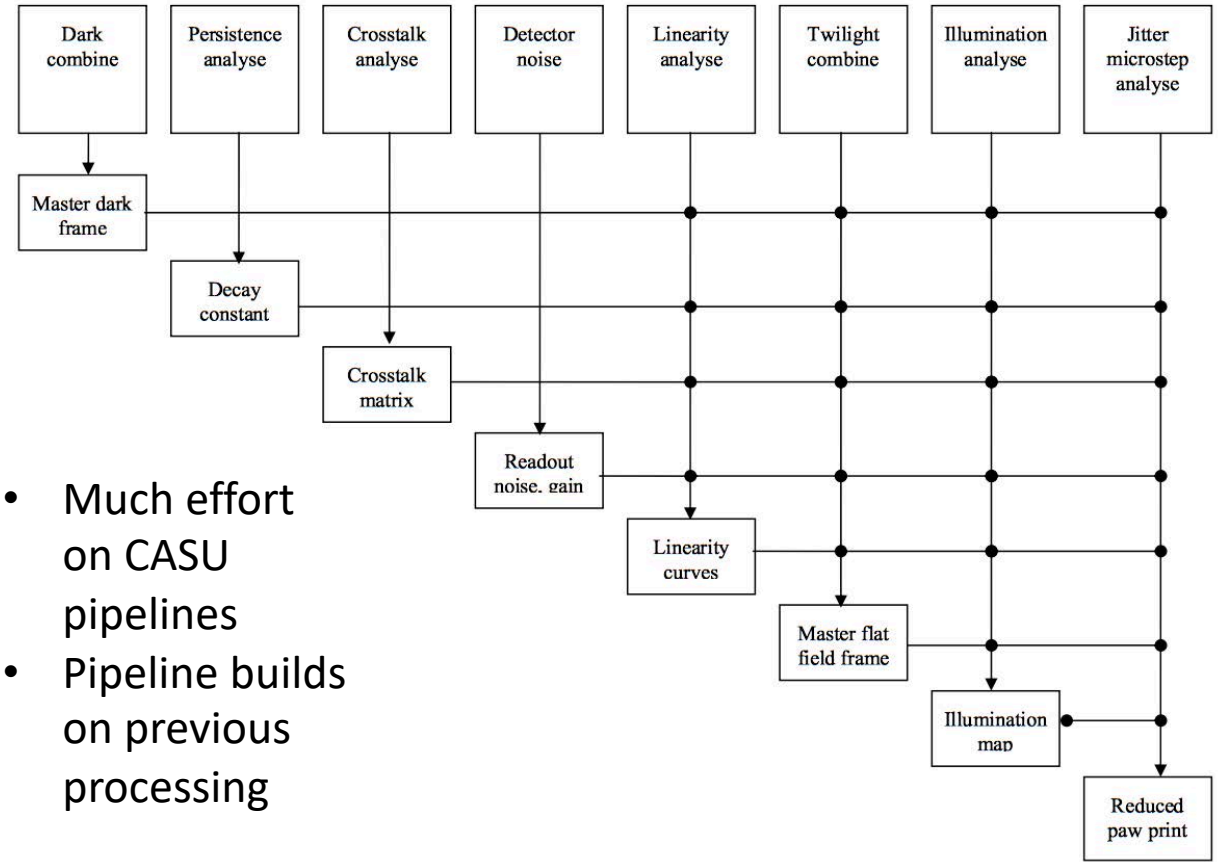
- Most of southern sky covered by VHS.
- Only JHKs coverage from VISTA for early Rubin years on some areas.



VISTA survey details

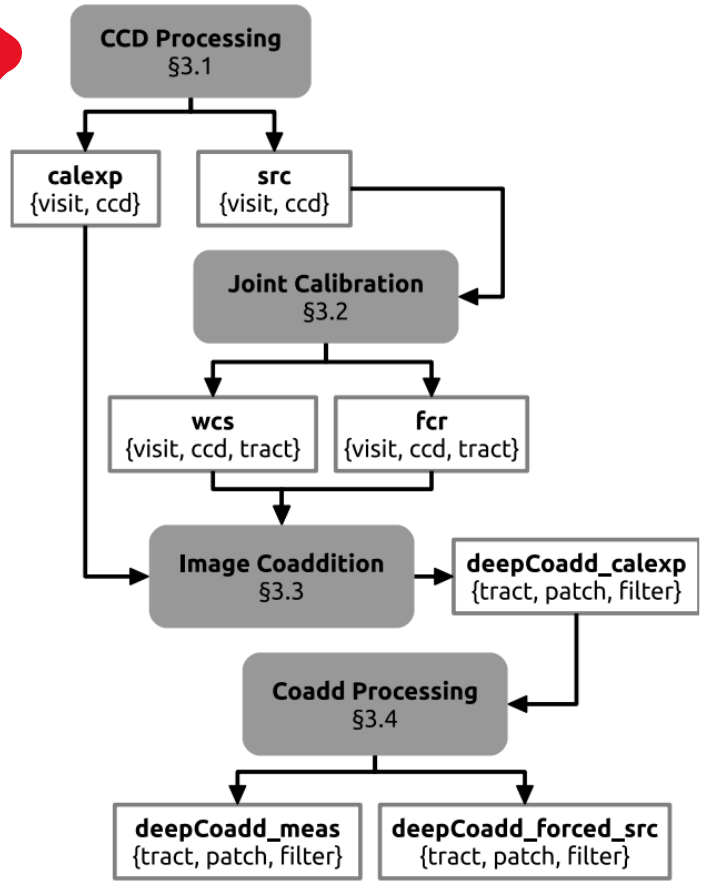
First cycle VISTA surveys						
Acronym	**Short Title**	**PI**	**Area (deg^2)**	**Filters and Depth Measure (mag (10σ, AB))**	**Depth (mag)**	**Total number of hrs executed (Nov. 2019)**
Ultra-VISTA	An Ultra Deep Survey with VISTA	J. Dunlop	0.73 (ultra-deep)	5σ, AB	Y=26.7 J=26.6 H=26.1 K_s=25.6 NB=26.0	1832
VIKING	The VISTA Kilo-degree Infrared Galaxy Survey	A. Edge, W.Sutherland	1500	5σ, AB	Z=23.1 Y=22.3 J=22.1 H=21.5 K_s=21.2	2424
VMC	The VISTA near-infrared survey of the Magellanic System	M.R. Cioni	184	10σ, Vega	Y=21.9 J=21.4 Ks=20.3	2047
VVV	Vista Variables in the Via Lactea	D. Minniti	520	5σ, Vega	Z=21.9 Y=21.2 J=20.2 H=18.2 K_s=18.1	2205
VHS	The VISTA Hemisphere Survey	R. McMahon	20 000	5σ, AB	Y=21.2 J=21.2 H=20.6 Ks=20.0	4623
VIDEO	VISTA Deep Extragalactic Observations Survey	M. Jarvis	12	5σ, AB	Z=25.7 Y=24.6 J=24.5 H=24.0 K_s=23.5	2073

CASU pipeline with LSST science pipelines



- Much effort on CASU pipelines
- Pipeline builds on previous processing

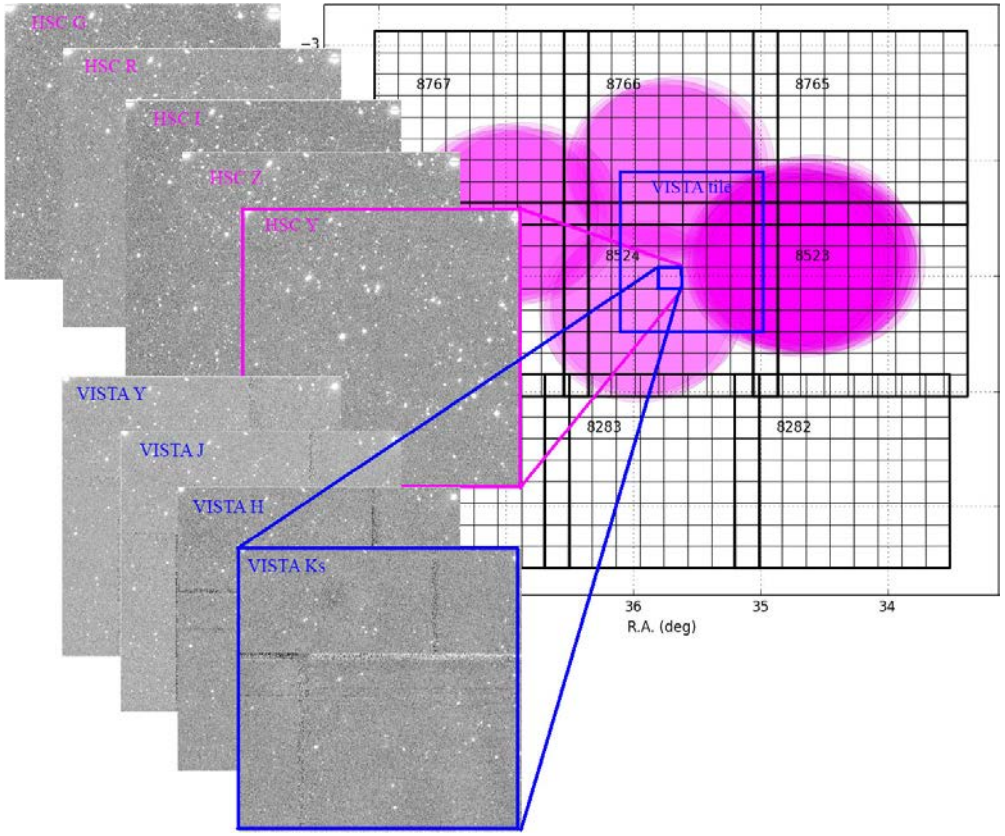
Irwin 1985 ++



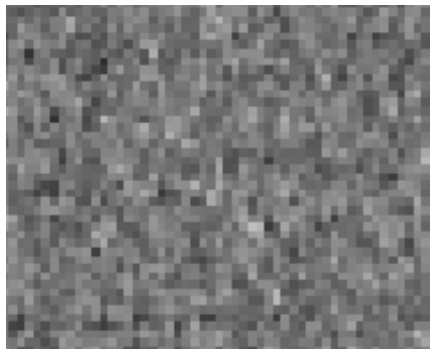
Bosch et al. 2018

Warping and coadding

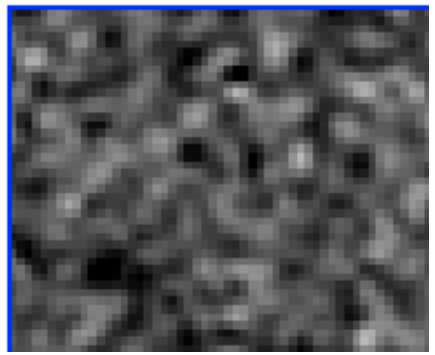
- Pixel matched imaging.
- One-one pixel matching between native Rubin/HSC and oversampled VISTA.
- Error propagation accounted for in final catalogues.
- Current HSC sky map:
  - Tracts approx. 1.7deg wide
  - Tract is broken into 9×9 patches
  - Pstches 4200 pixels on a side
  - Overlap of 1 arcmin between the two adjacent tracts. Patches overlap by 200 pixels (~34 arcsec)
  - HSC pixel = 0.168 arcsec
- LSST sky map to be defined



before

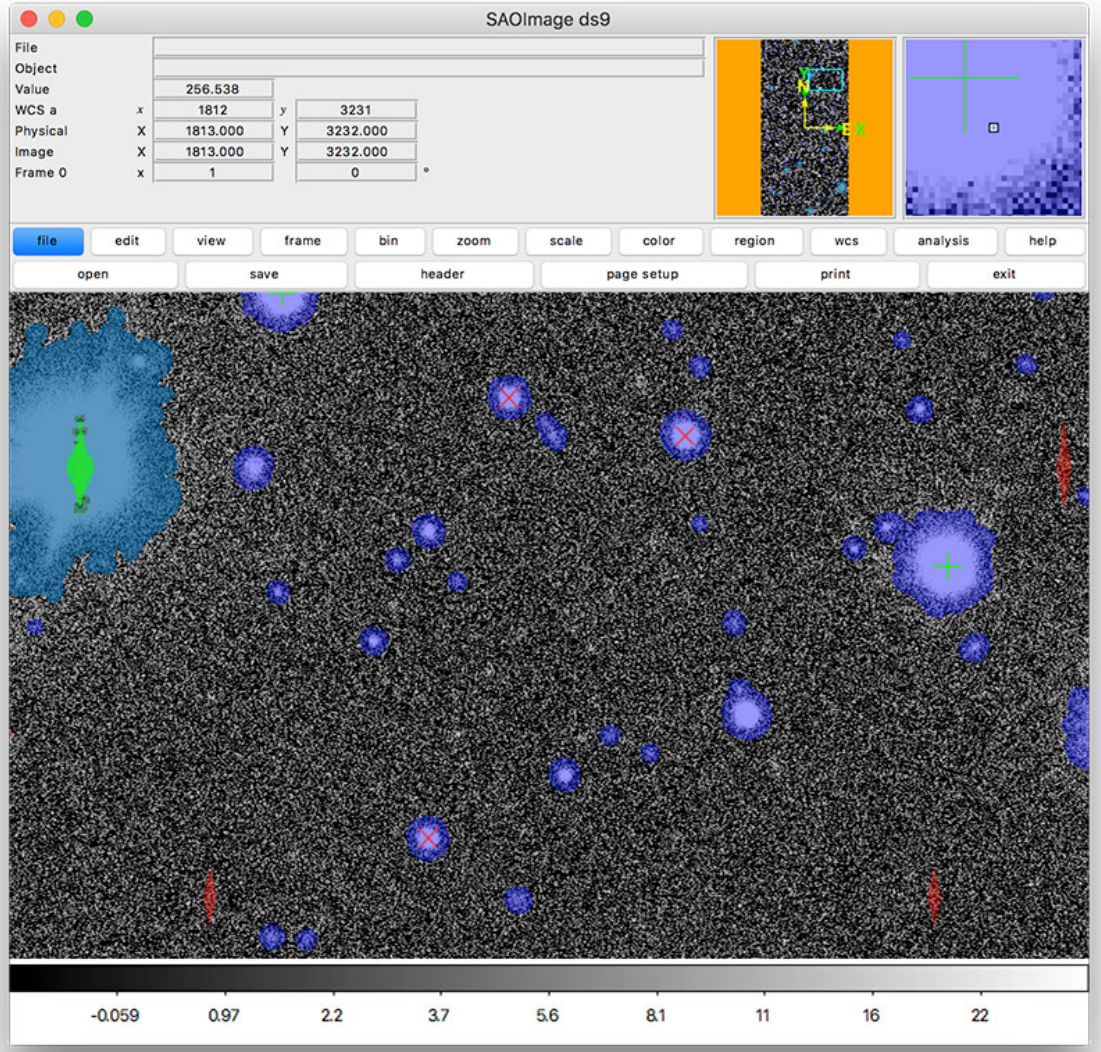


after



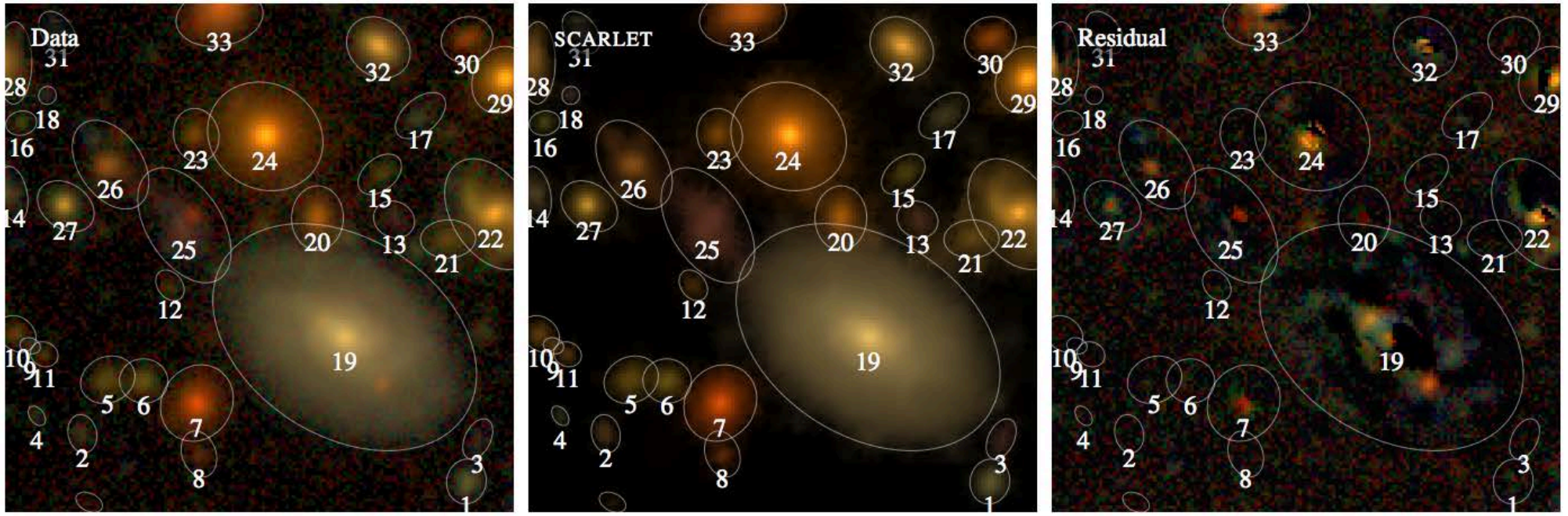
Photometry

- Detected in any band measured in every band
- Measurement and forced catalogues
- Deblended pixels and fluxes
- Aperture, Convolved aperture, Cmodel, Kron fluxes.




```
DETECTED_NEGATIVE: cyan
CROSSTALK: None
INTRP: green
DETECTED: blue
UNMASKEDNAN: None
NO_DATA: orange
BAD: red
EDGE: yellow
SUSPECT: yellow
NOT_DEBLENDED: None
CR: magenta
SAT: green
```

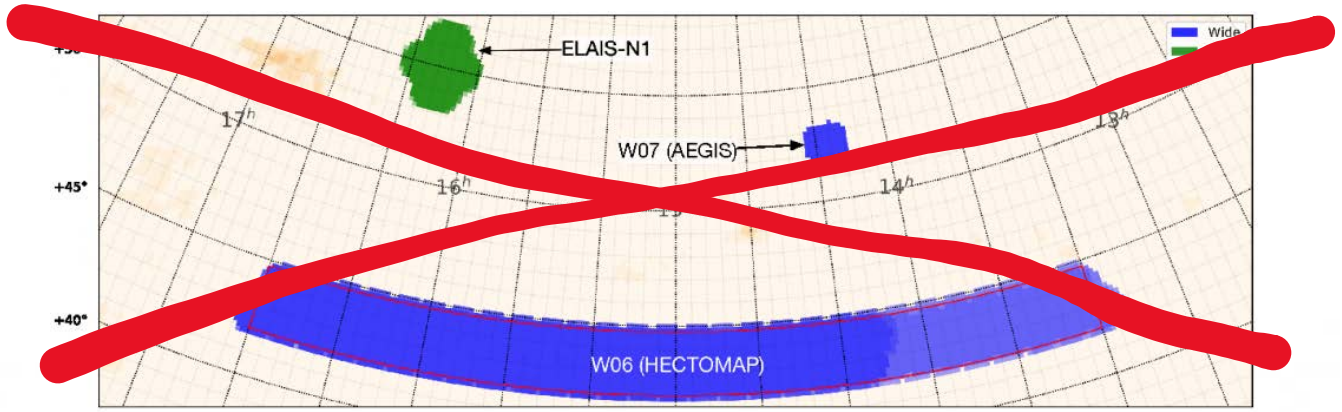
SCARLET (Melchior et al., 2018)

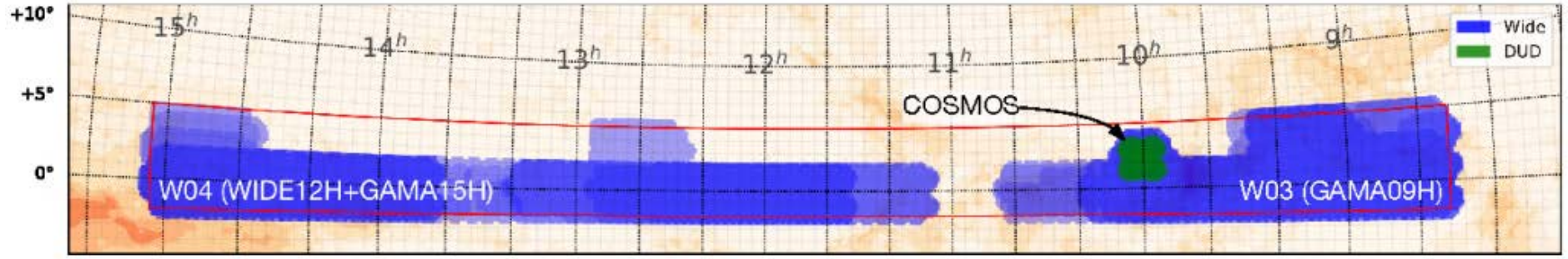


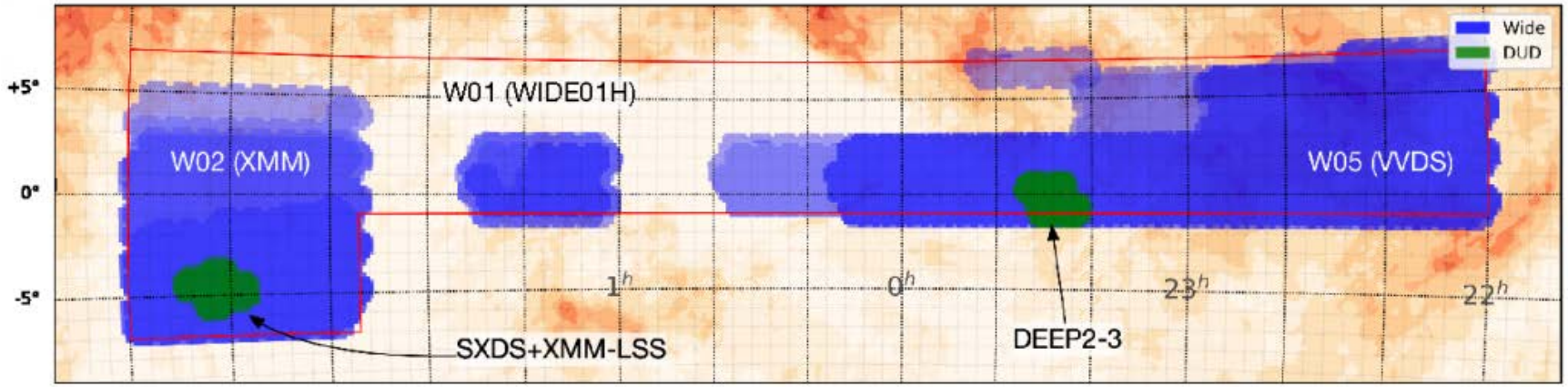
- JHKs adds colour information.
- Working on metrics to understand impact of extra VISTA bands.
- Sub population of objects where VISTA particularly helpful.

HSC overlap

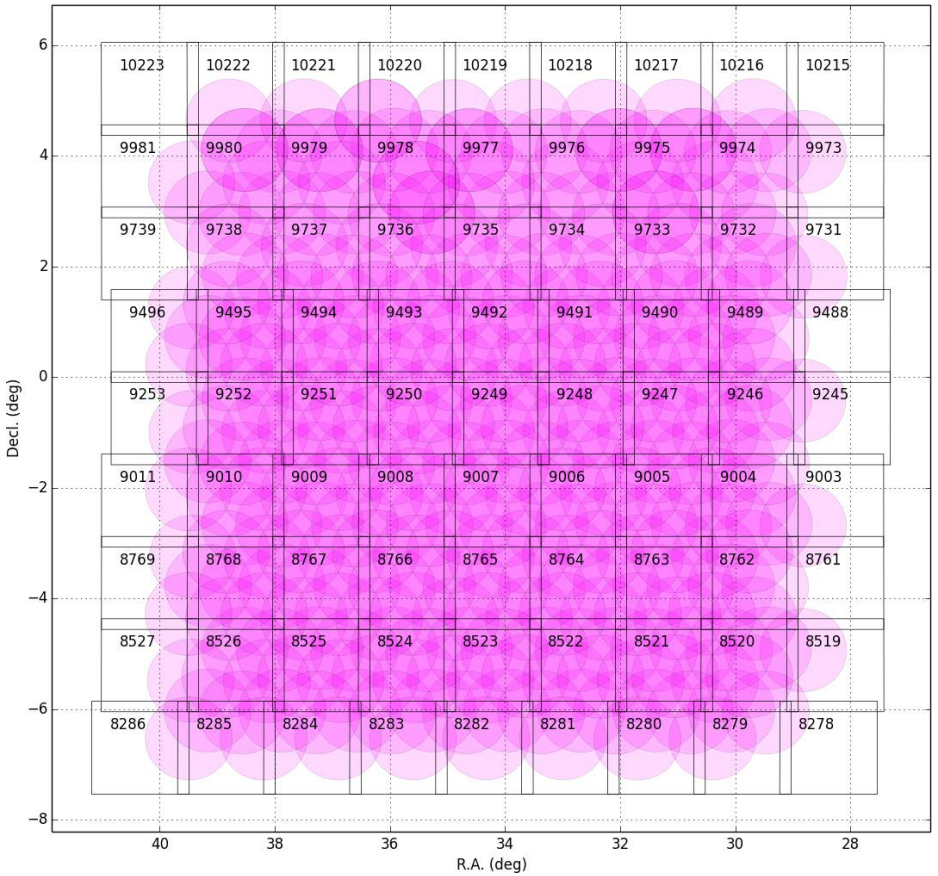
~800 square degrees processing area
~300 tracts, each 9*9=81 patches.

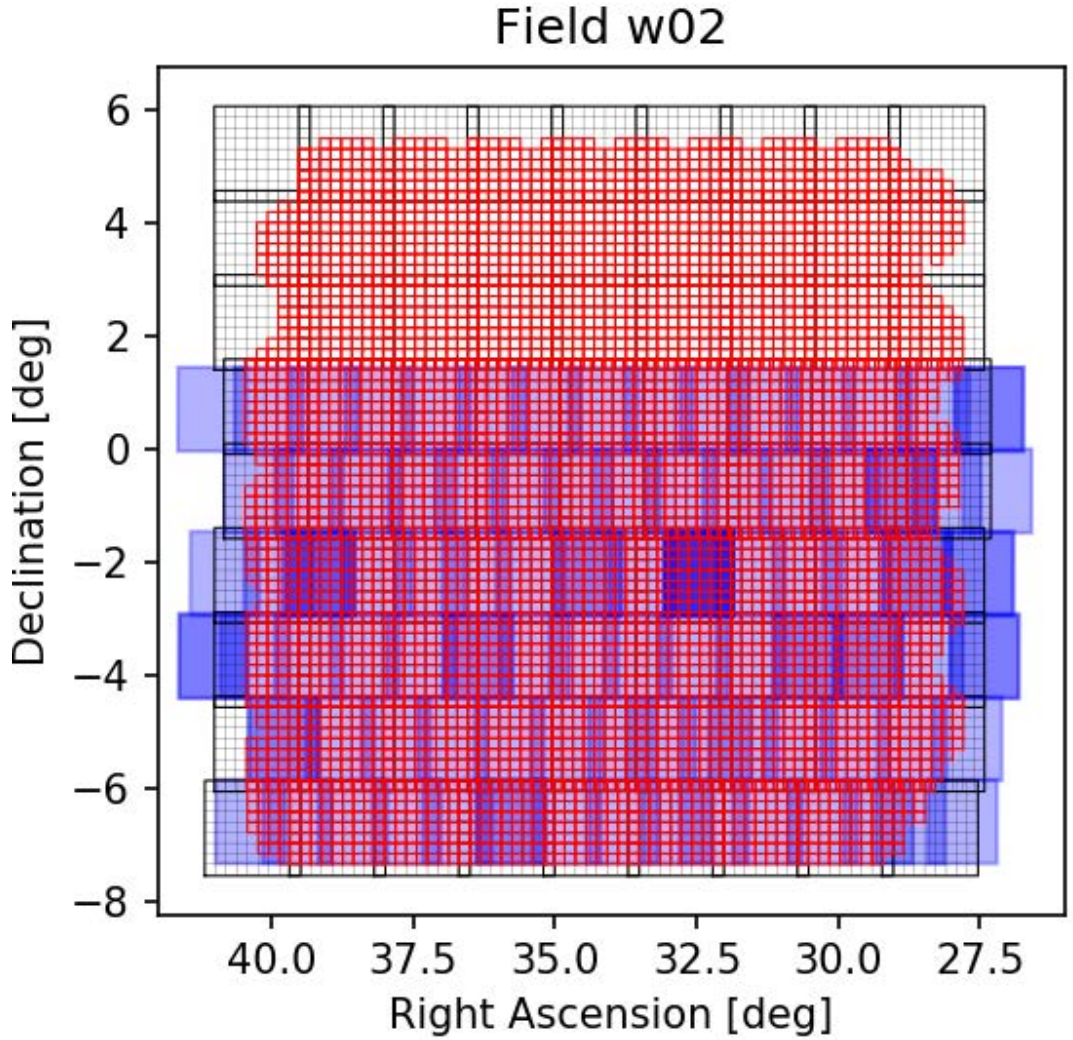






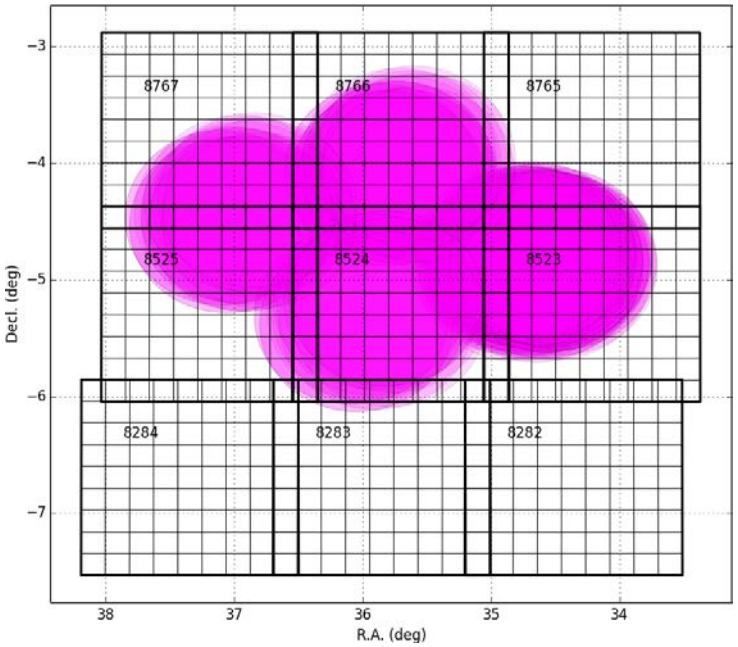
HSC Wide W02 XMM and VHS overlap

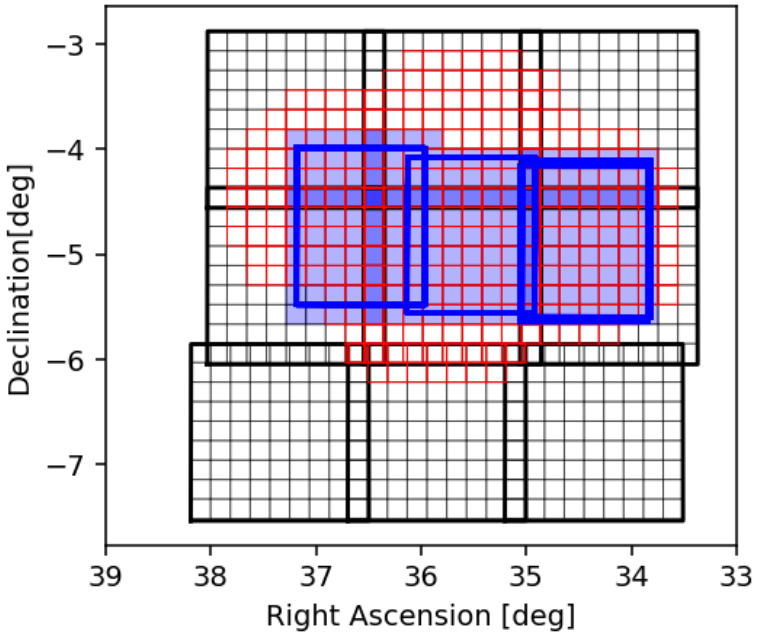




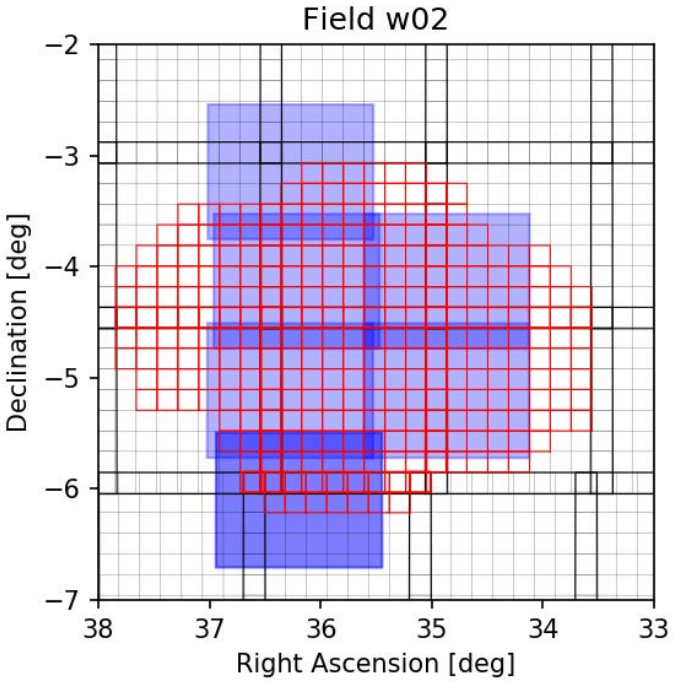
Pink: HSC r pointings, red: HSC patches, blue: VHS tile pointings

HSC DUD SXDS VHS/VIKING/VIDEO test field





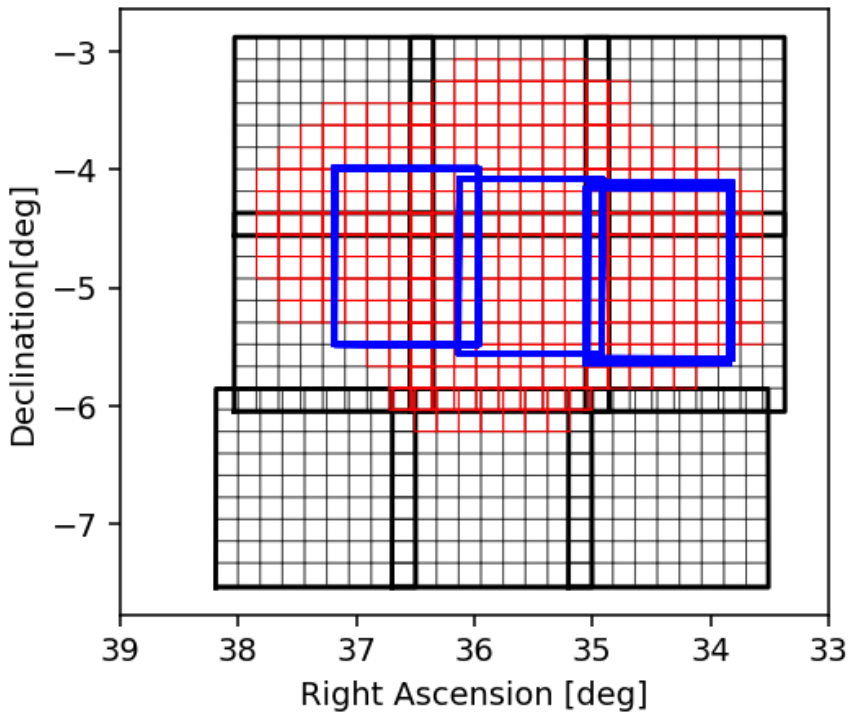
VIDEO

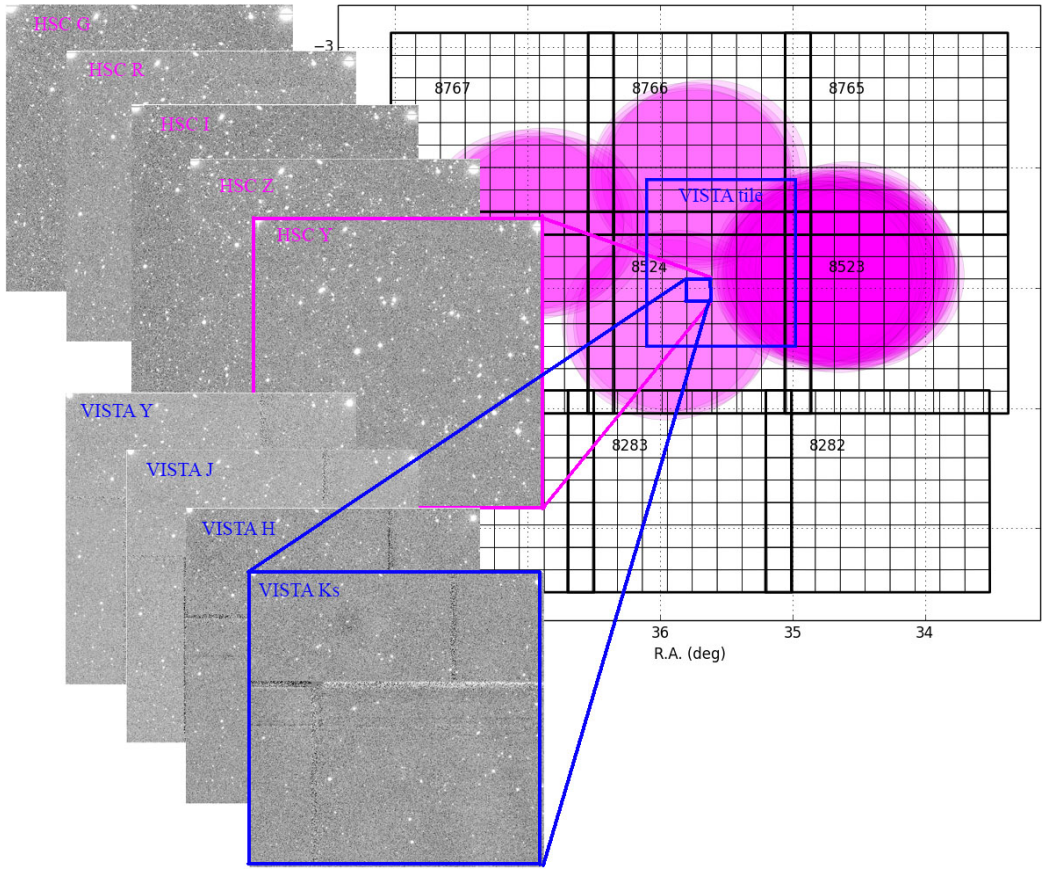


VIKING

Pink: HSC r pointings, red: HSC patches, blue: VHS tile pointings

SXDS HSC uDeep VISTA VIDEO prototype



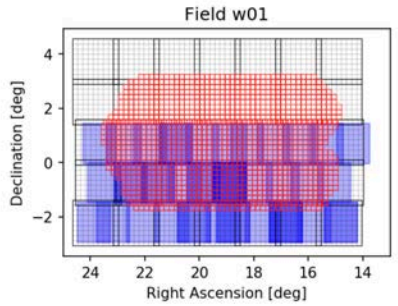


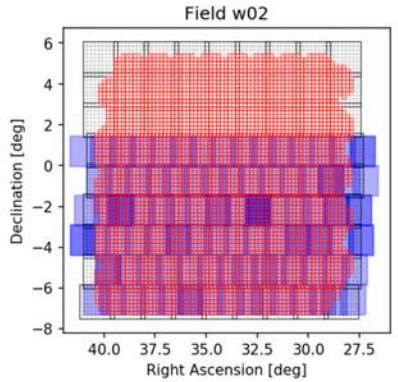
- 219 patches
- 5263 stack images

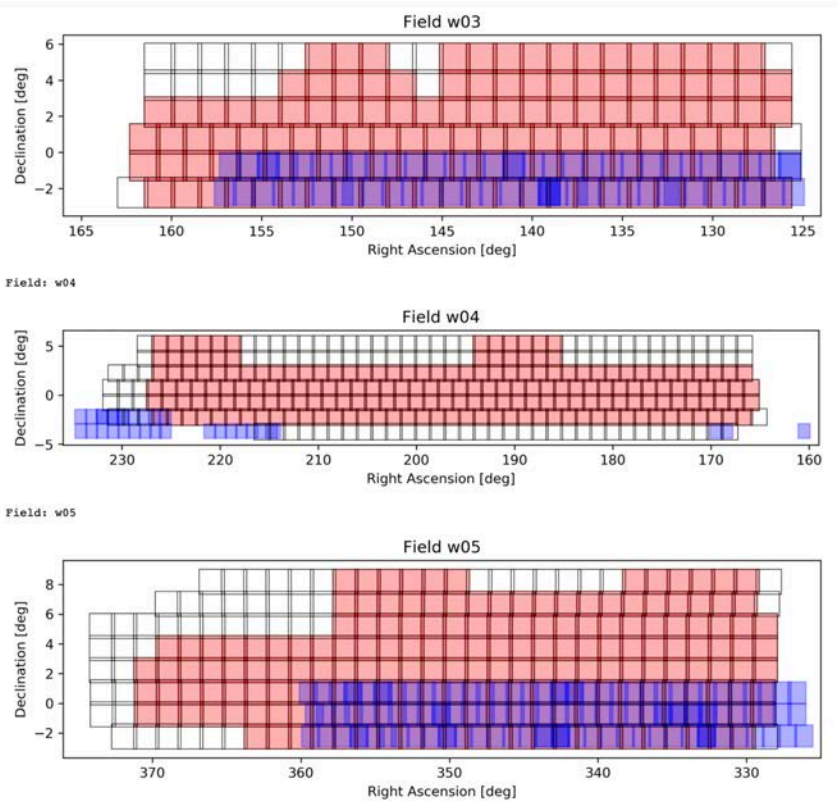
Pink: HSC r pointings, red: HSC patches, blue: VHS tile pointings

Full overlap with HSC PDR2

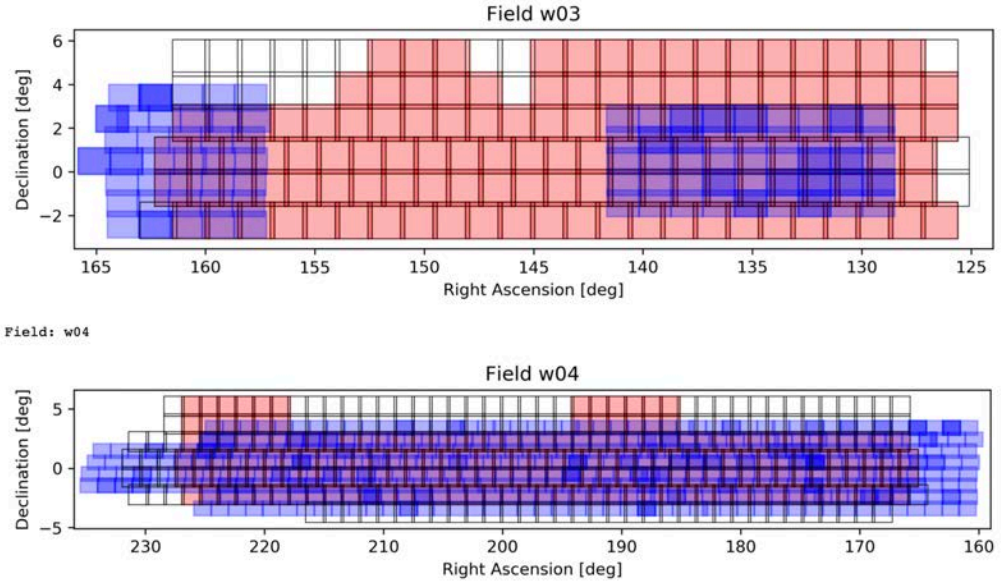
VHS





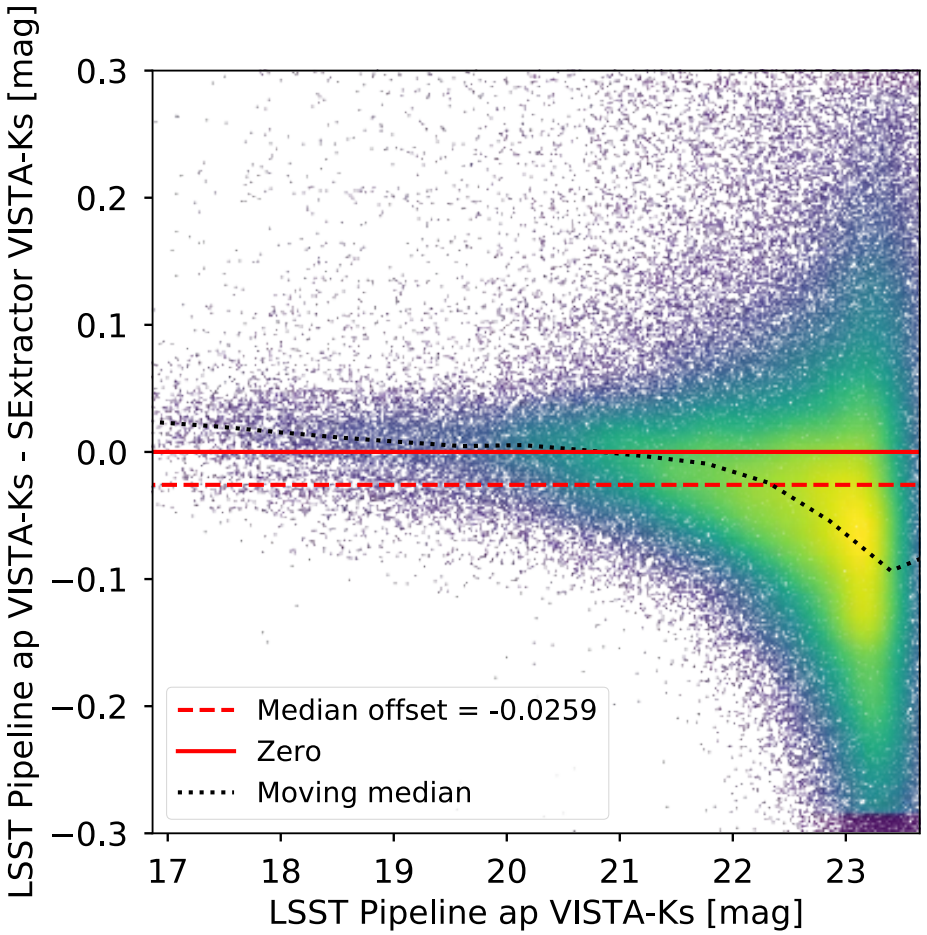


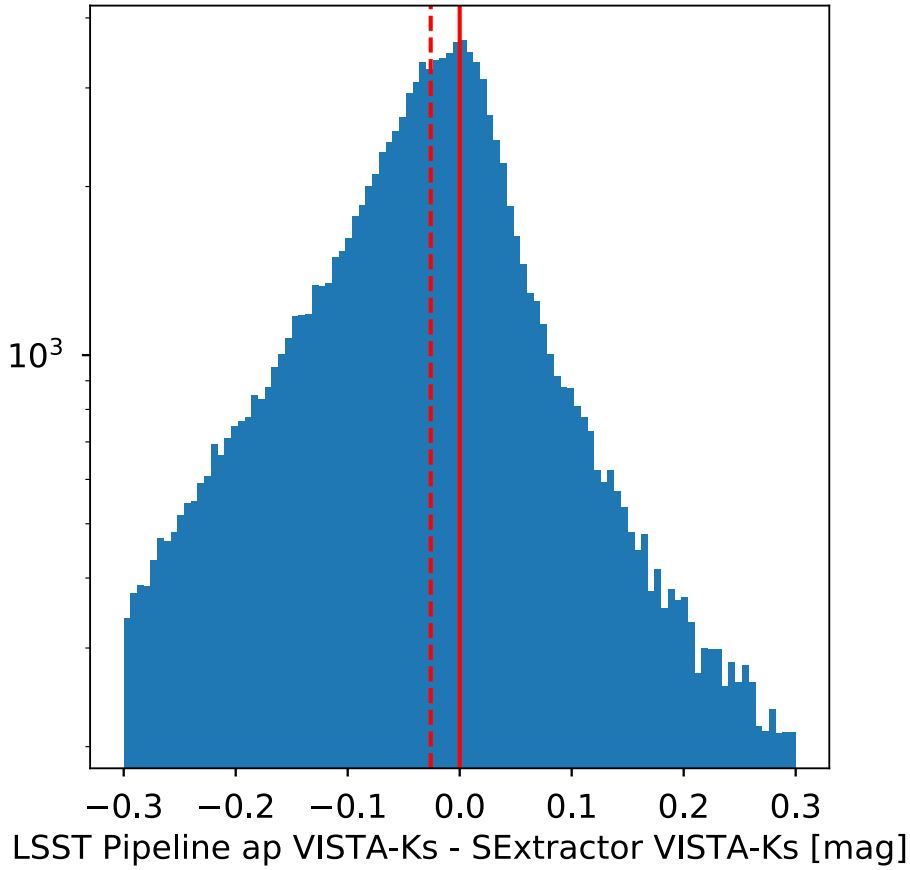
VIKING



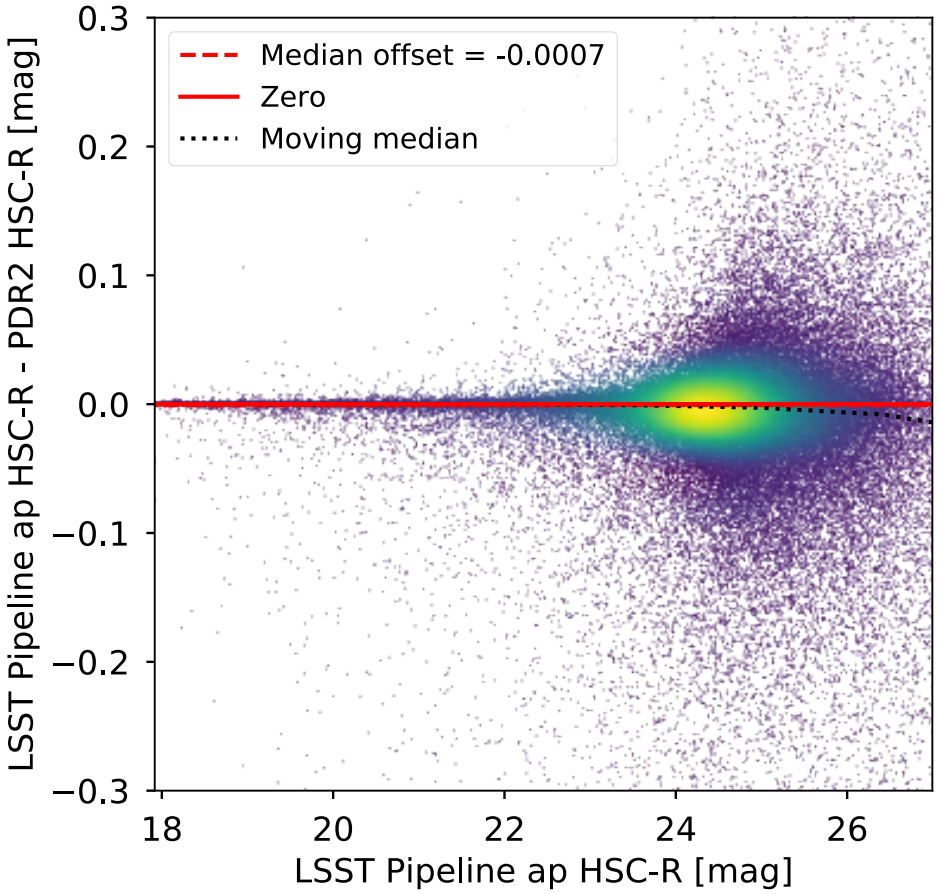
Red: HSC tracts, blue: VHS tile pointings

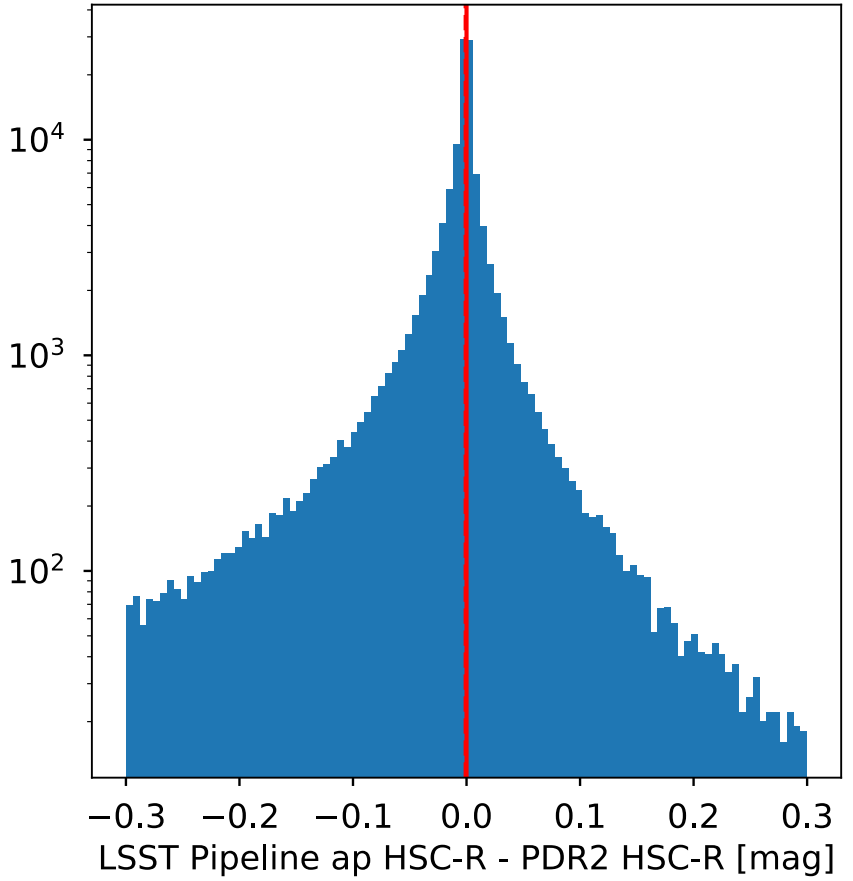
Quality control





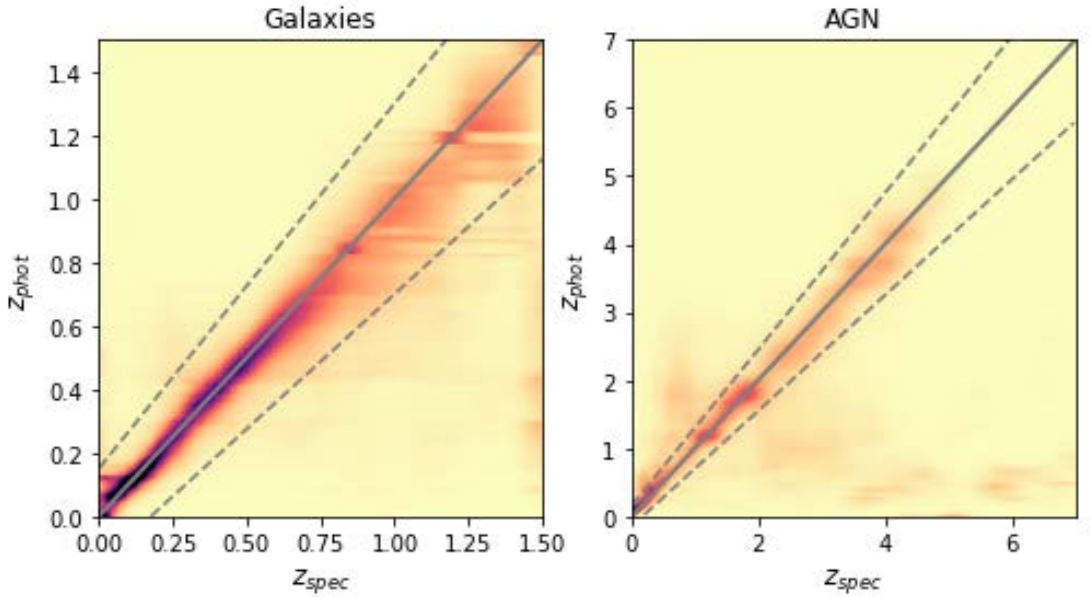
Quality control



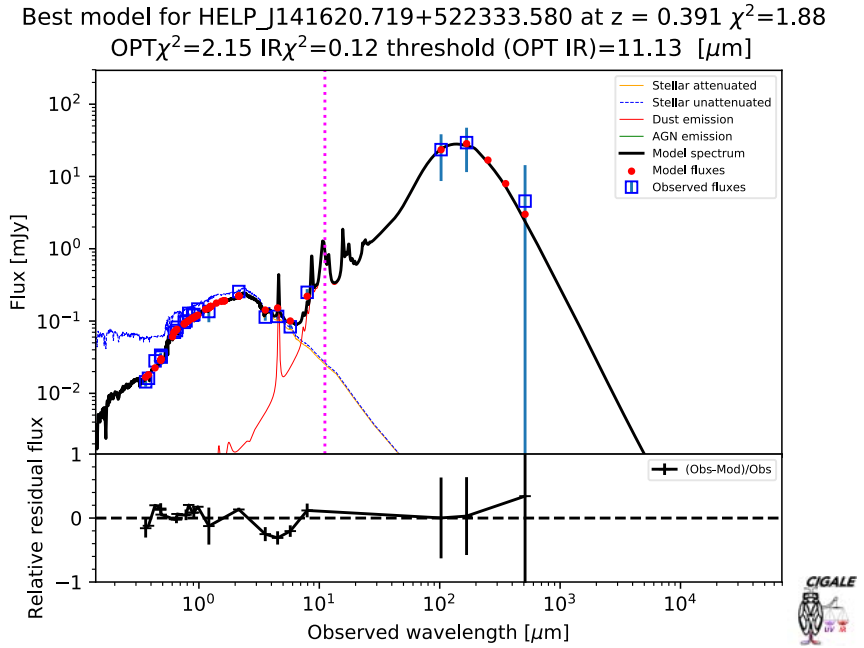


Scientific tests

- Photo-z
- SEDs
- PhD projects
- Community involvement

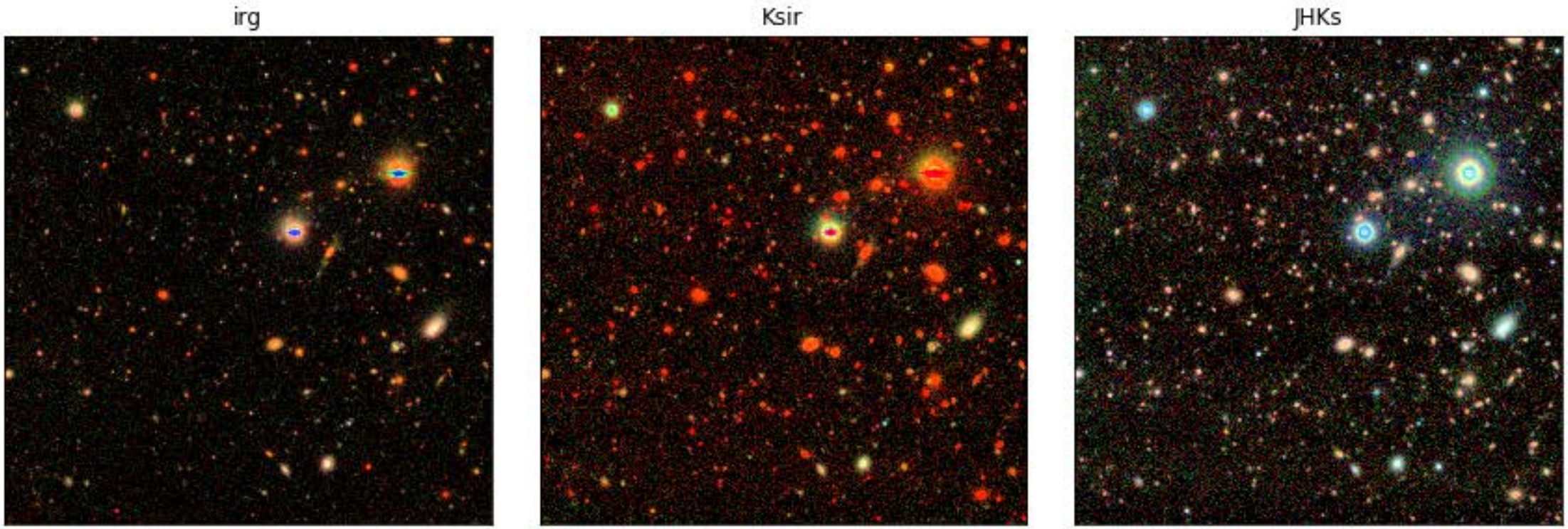


Dunken et al. 2018



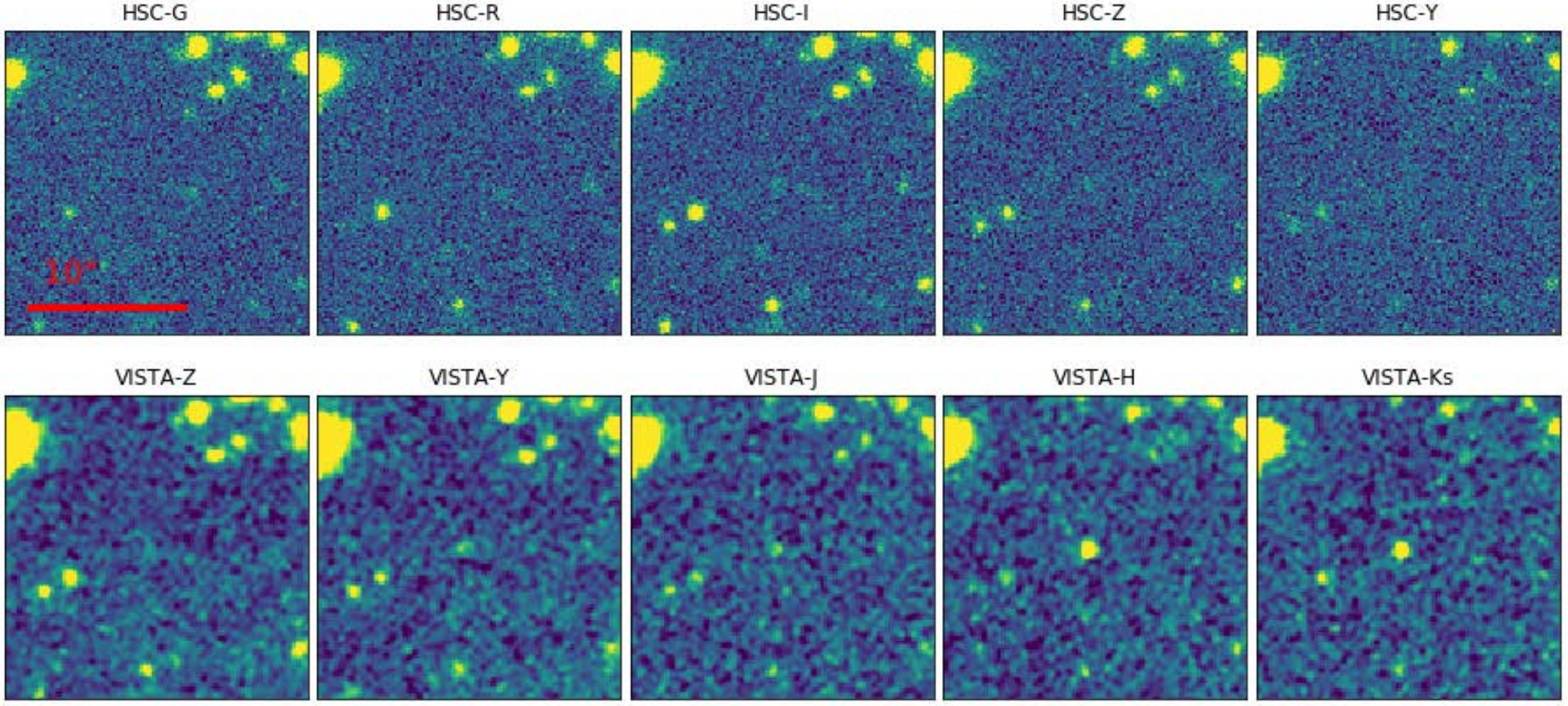
Małek et al. 2018,
Riccio et al. (in proc)

Example 1, Cluster z~1.8



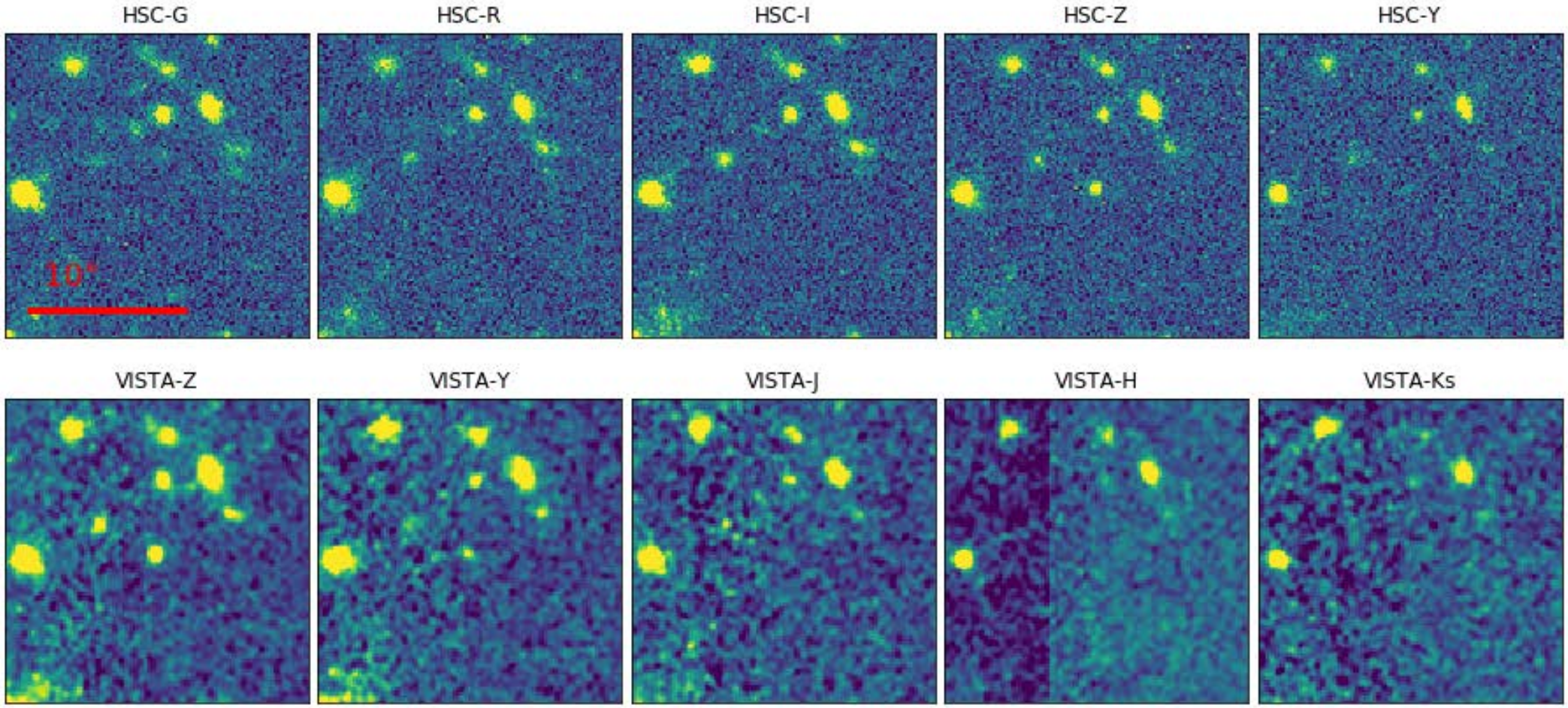
Andreon et al. (2018) JKCS 041: a Coma cluster progenitor at z = 1.803

Example 2, Extremely red object, z~2.5



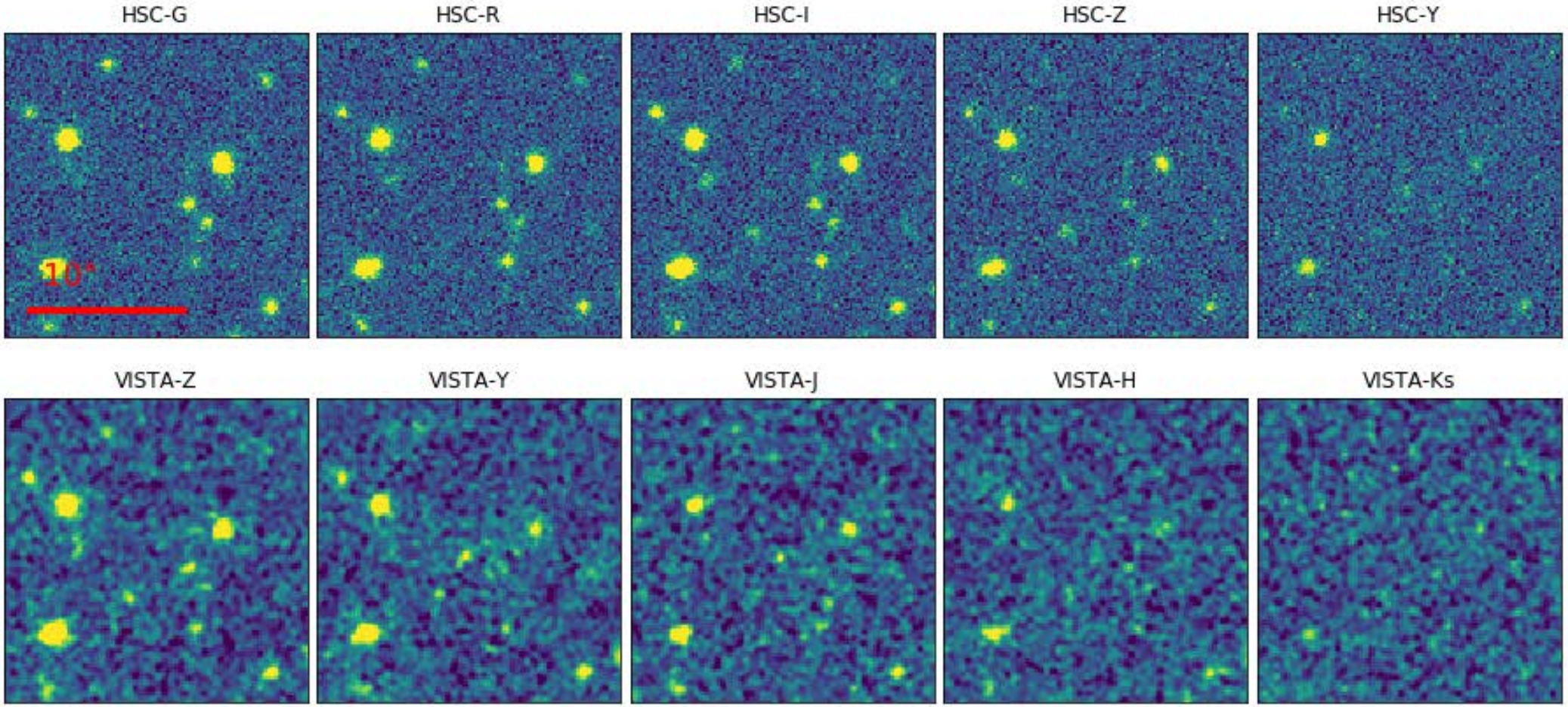
Candidate passive galaxies and/or very dusty star-forming galaxies/AGN from Castro-Rodrıguez et al. (2018)

Example 3, redshift 6 quasar



Wilott et al. (2010)

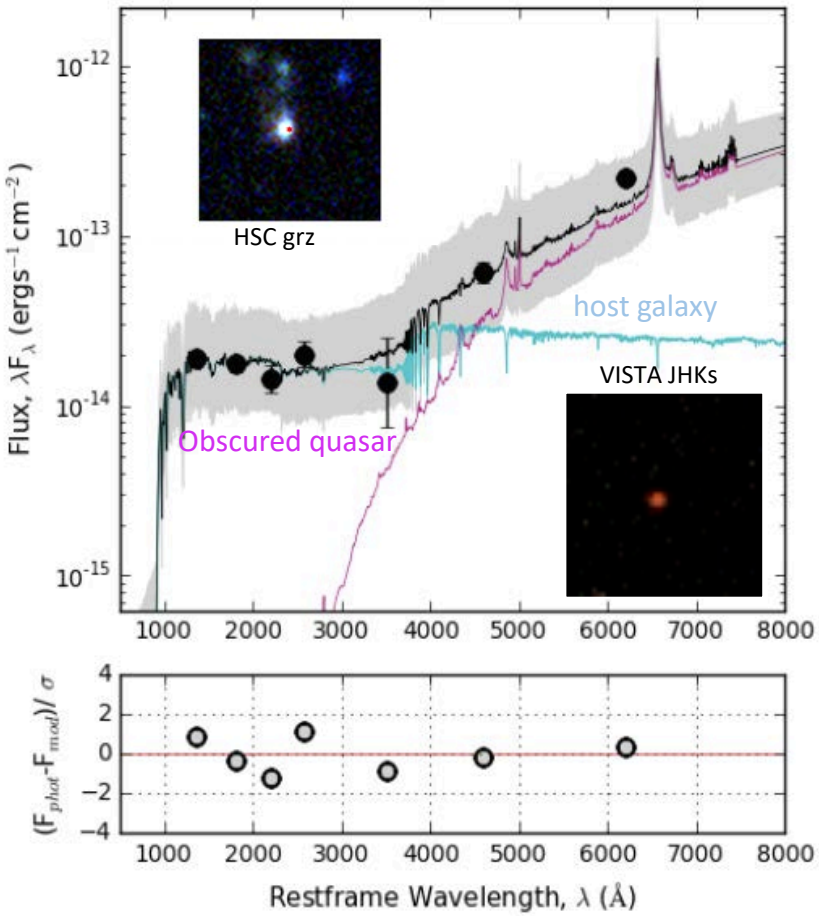
Example 4, LBG 6.5< photoz < 7.5



Bowler et al. (2014, 2016)

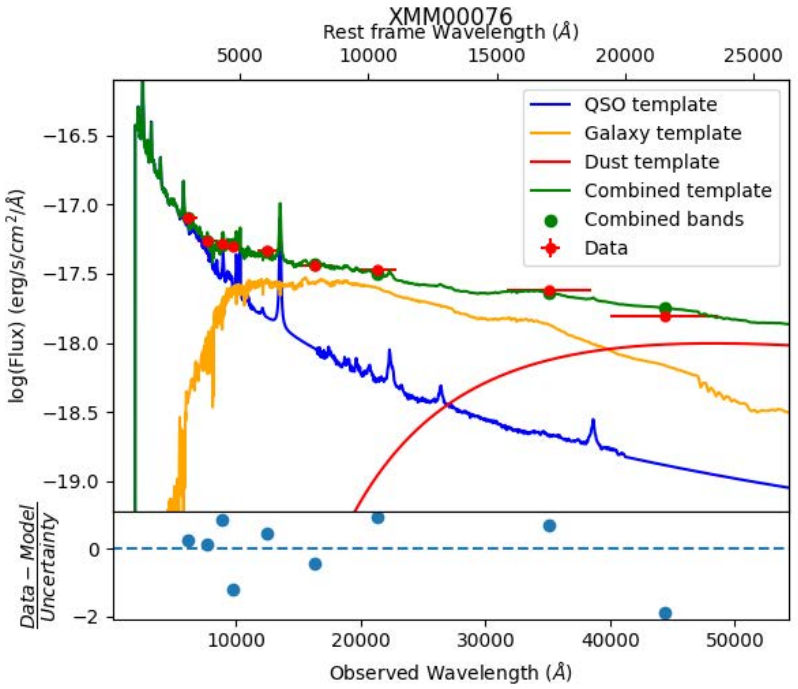
AGN Host Galaxies, 2 examples

- Obscurred quasar at z=2.5
- HSC shows extended emission from star forming host
- ALMA imaging reveals host is major merger



Wethers+18, Banerji+21

HSC grz

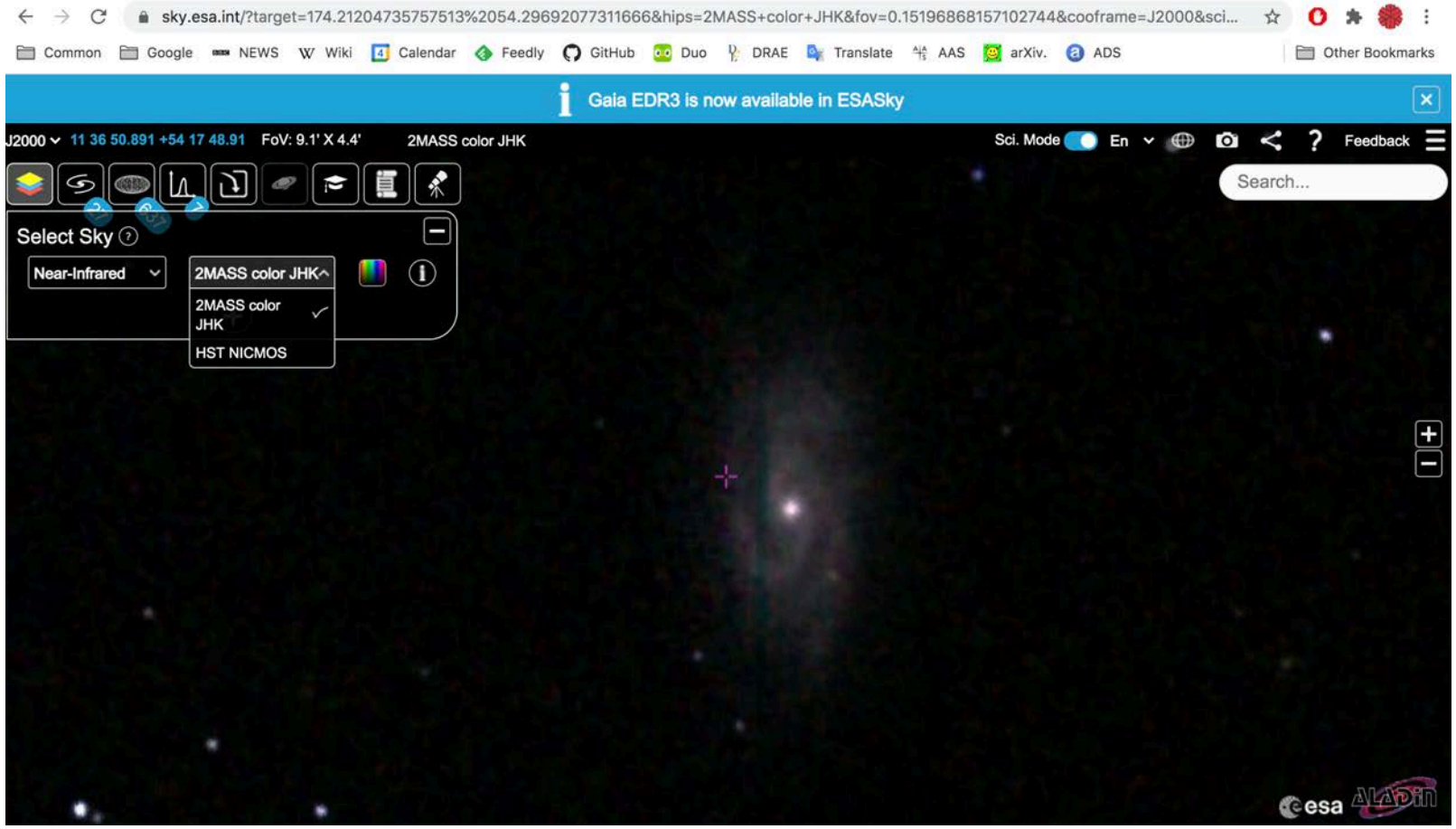


Marshall+ in prep

- Blue unobscured AGN at z=1.1
- dominating HSC
- Dominating SED at red end

Serving the data

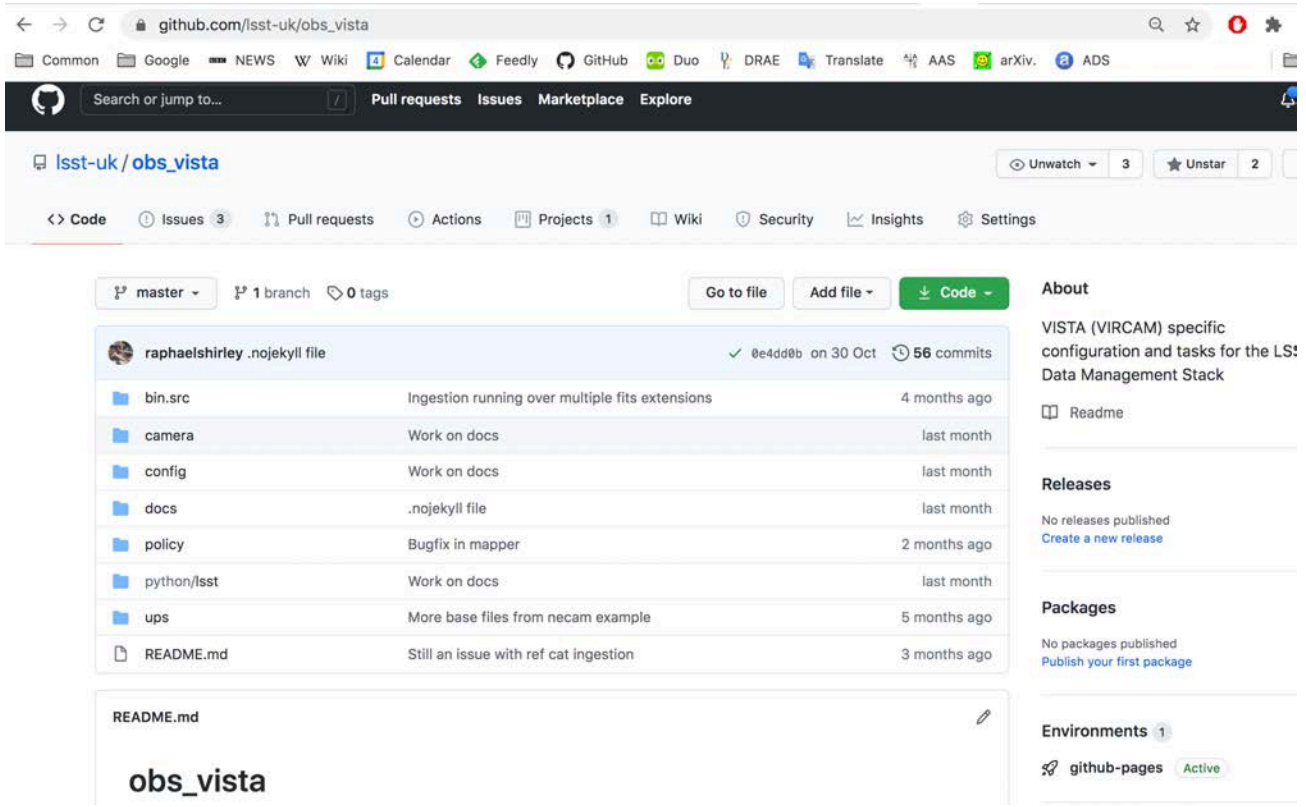
- VISTA Science Archive table access.
- Raw files/Butler.
- Aladin all sky VHS viewer.
- Rubin Science Platform.
- QServ



GitHub 1: obs_vista

- Python module for LSST science pipelines
- Open and documented with Sphinx
- Joint Butler 2 and 3 capability
- Developed from obs_necam (Mullaney et al., 2021)

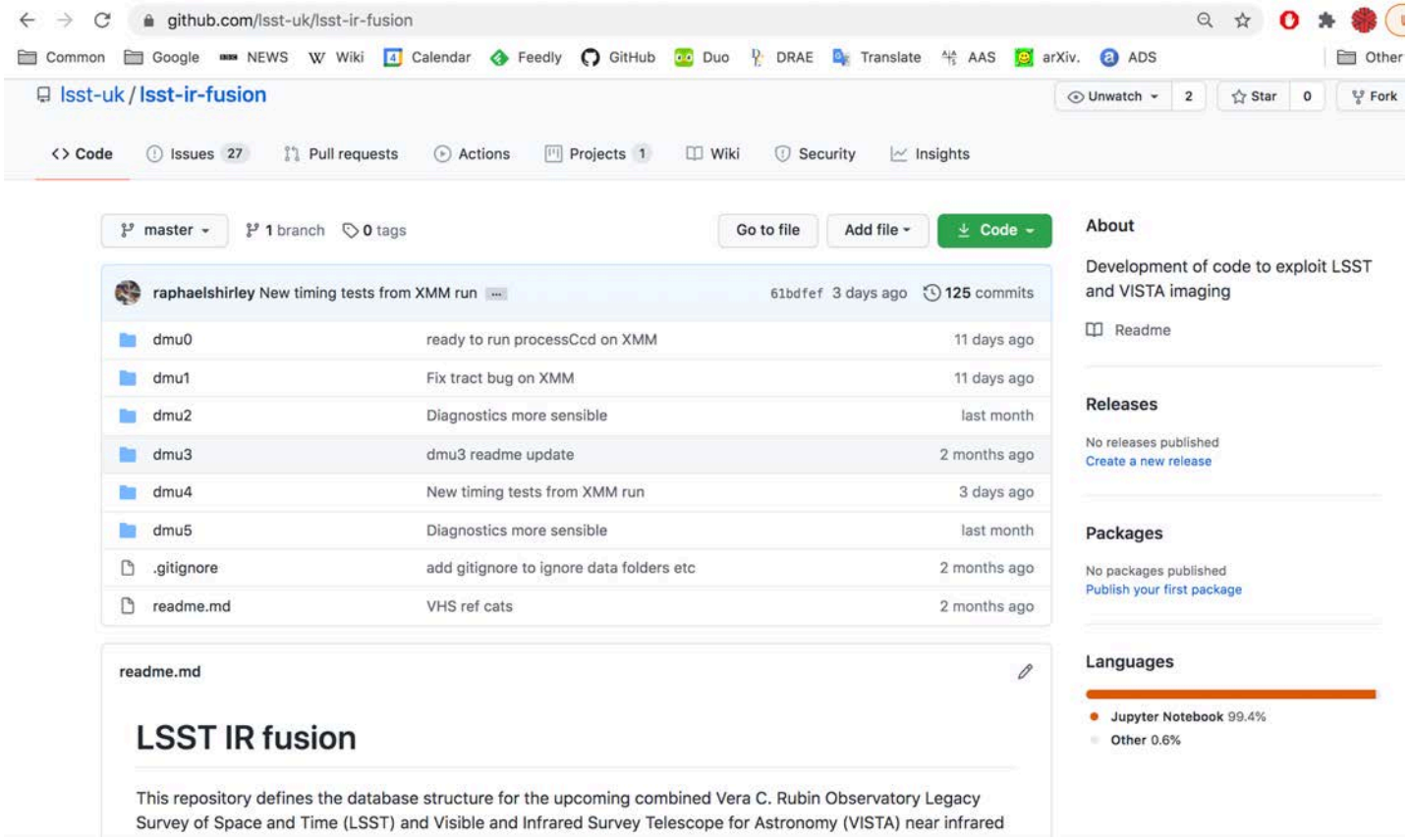
```
In [ ]: from lsst.obs.vista import vistaFilters
```



https://github.com/lsst-uk/obs_vista

GitHub 2: lsst-vista-fusion

- Database structure
- Documented and public
- Jupyter notebooks for diagnostics and job processing



https://github.com/lsst-uk/lsst-ir-fusion/

Conclusions

- Aperture matched photometry from Rubin ugrizy and VISTA ZYJHKs.
- XMM-SXDS HSC prototype produced and testing started.
- Full VIDEO, VHS, VIKING Wide overlap in next months.
- Everything in place for first datasets at start of operations.
- All code is public.