



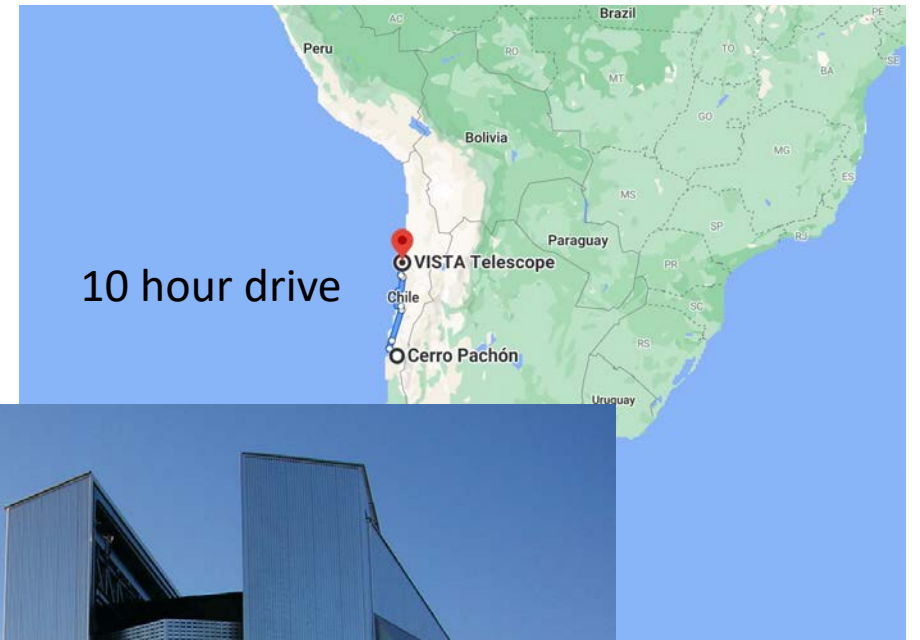
# Joint processing of Vera C. Rubin Observatory optical and VISTA VIRCAM near infrared imaging data

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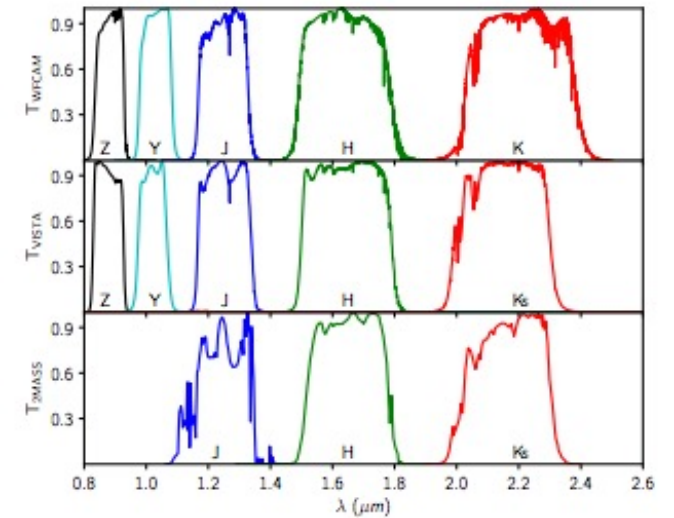
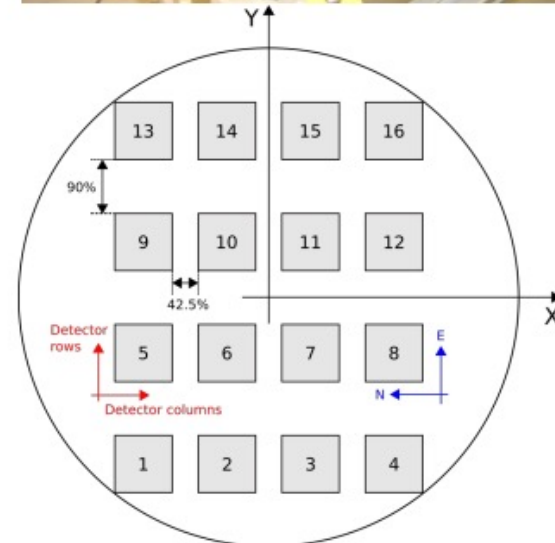
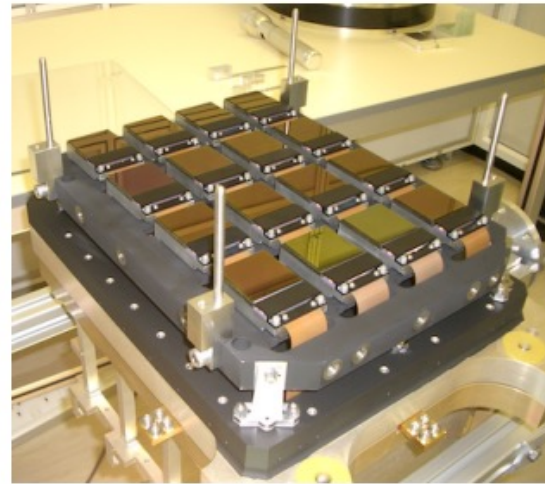
# VISTA (Visible and Infrared Survey Telescope for Astronomy)

- 4-m class
- 0.339 arcsec pixels
- 1.65 deg<sup>2</sup> 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)

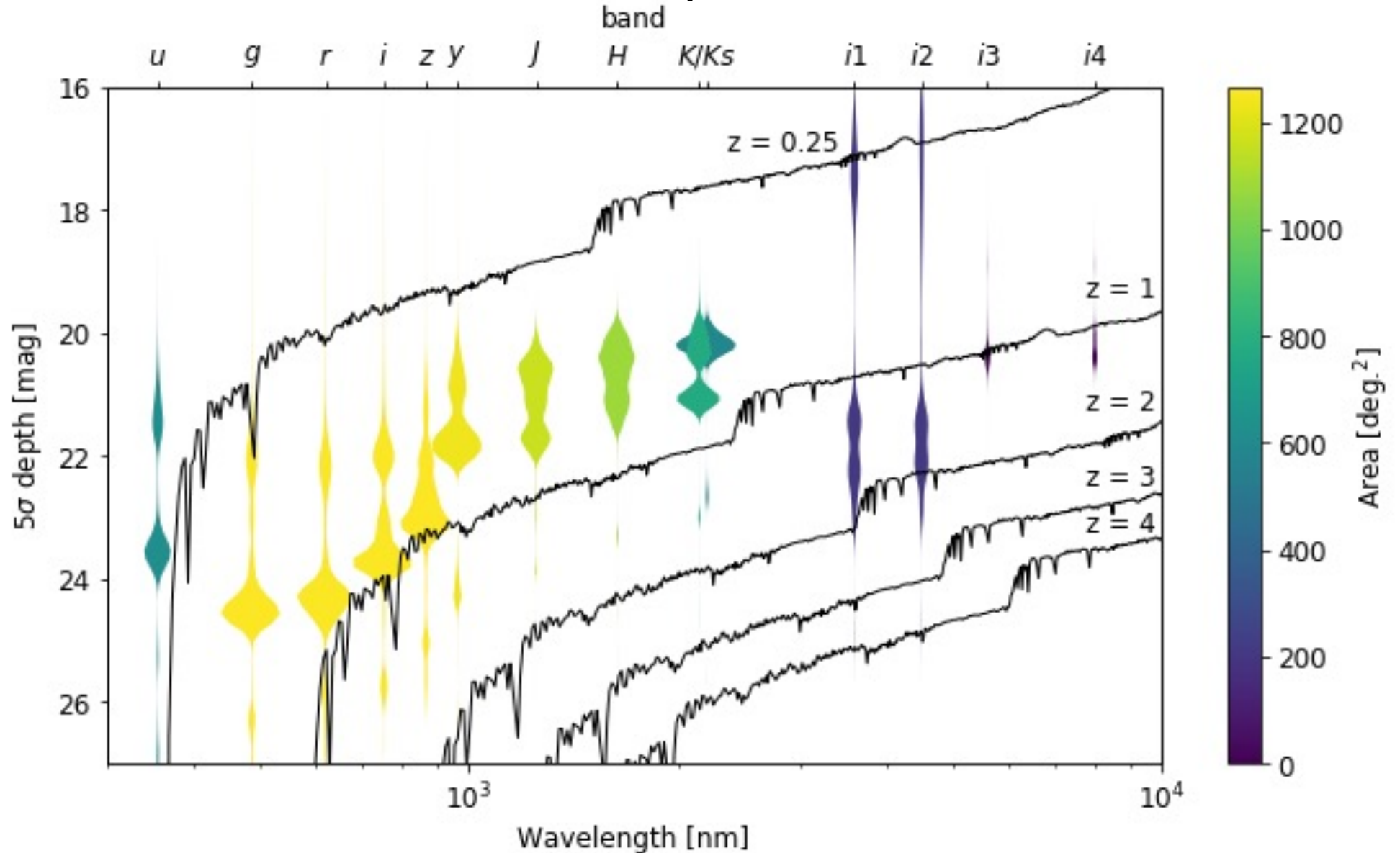
- JHKs key additional value filters
- Adds key near infrared coverage



González-Fernández et al. 2015

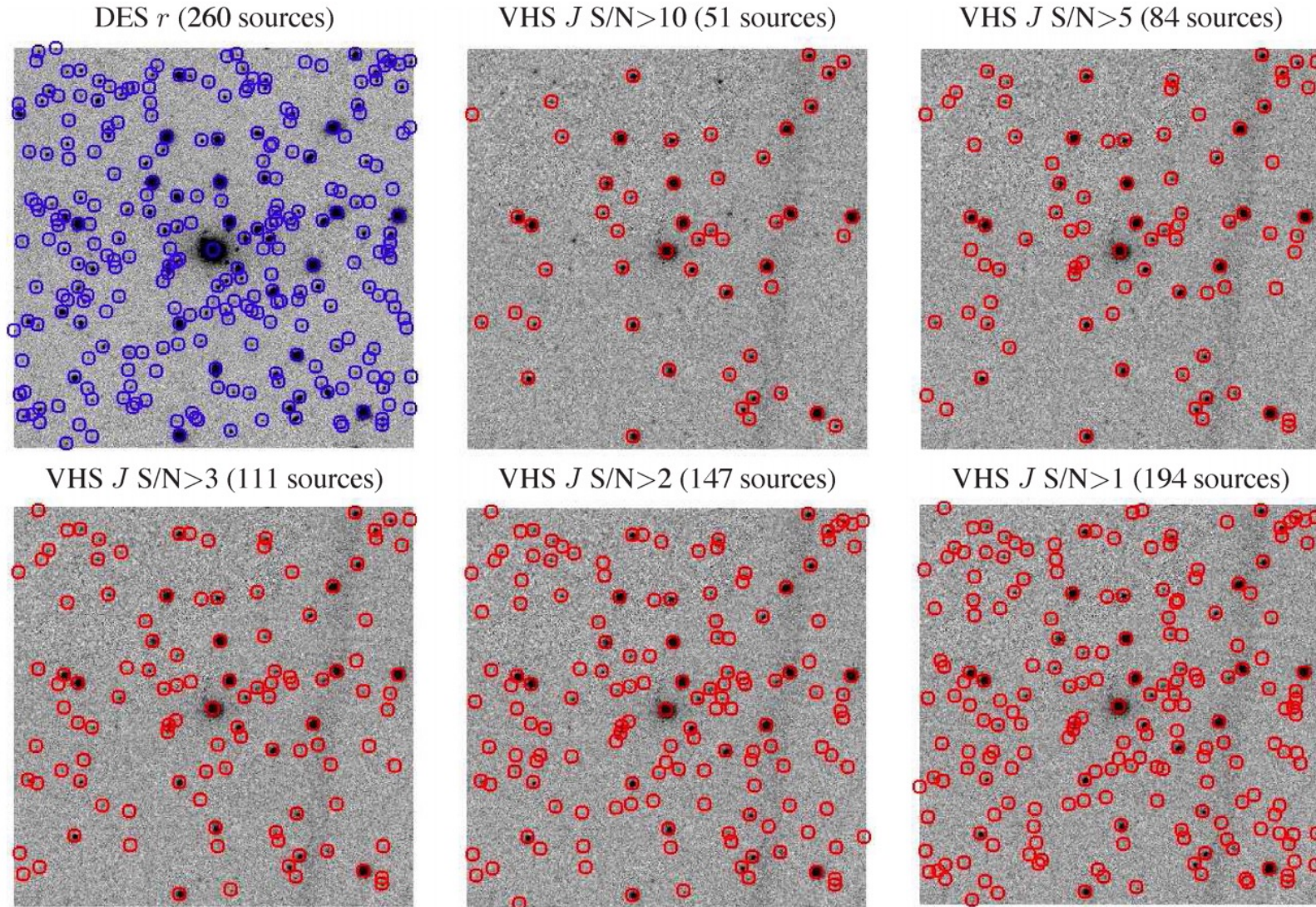
# Depth distributions on deep *Herschel* fields

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



# Many low s/n VISTA sources are real

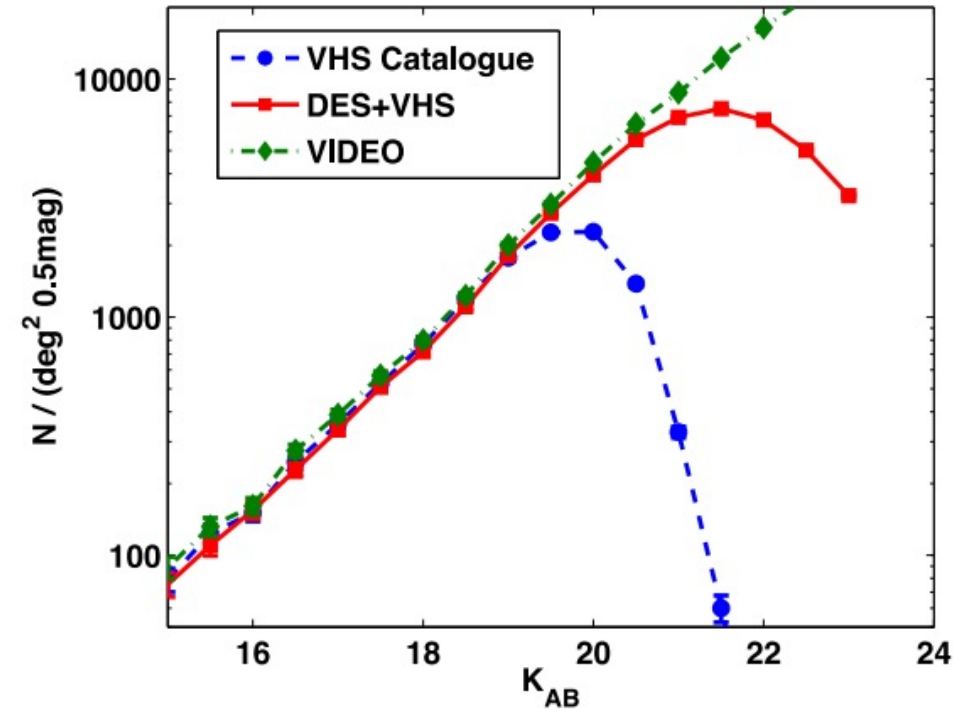
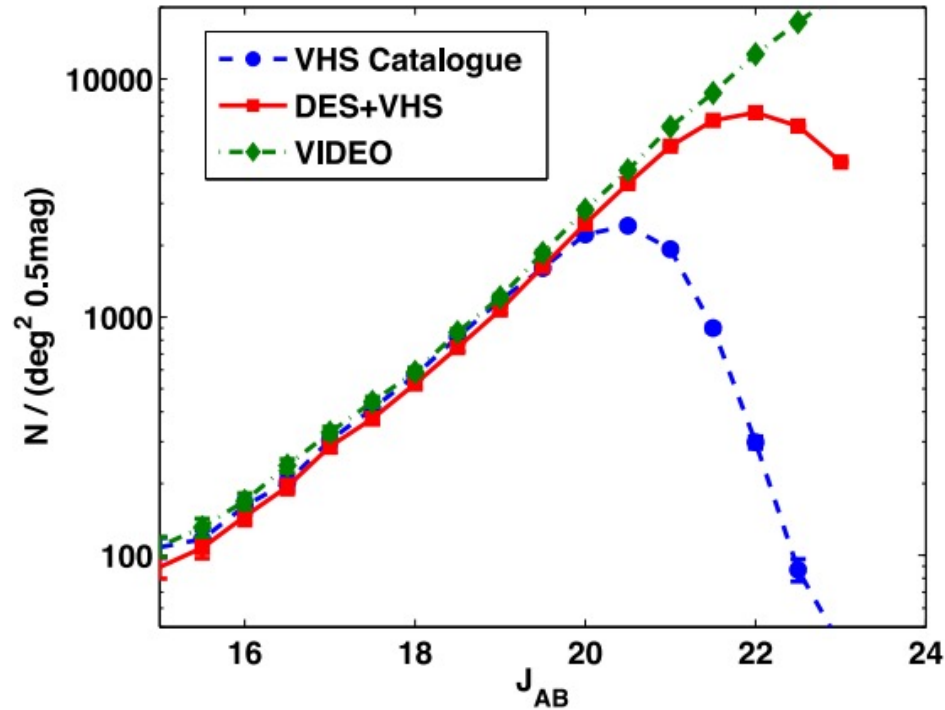
- Can be confident objects are not artifacts from other bands.
- Multiple low S/N measurements still have constraining power.



Banerji et al. 2015

# Harnessing optical depth to drive low s/n numbers

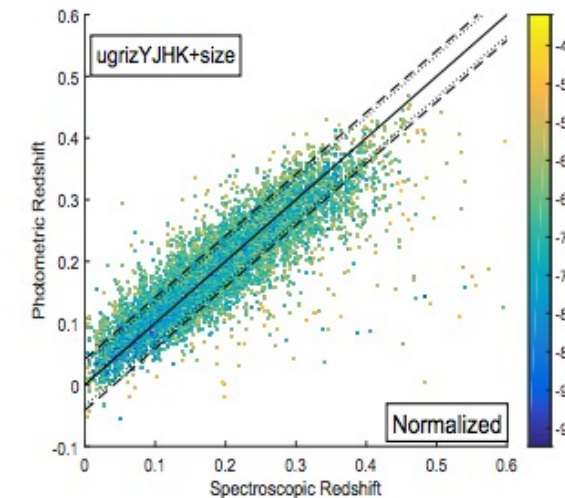
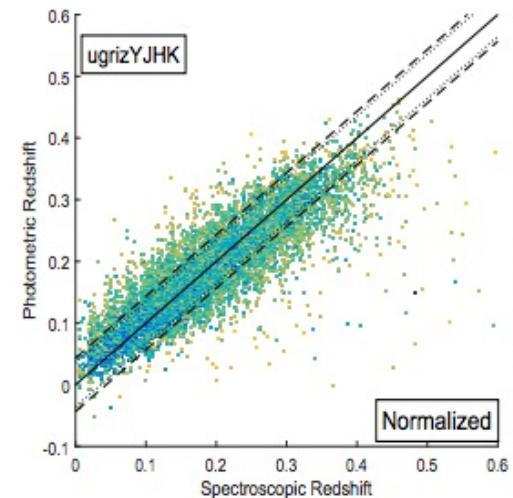
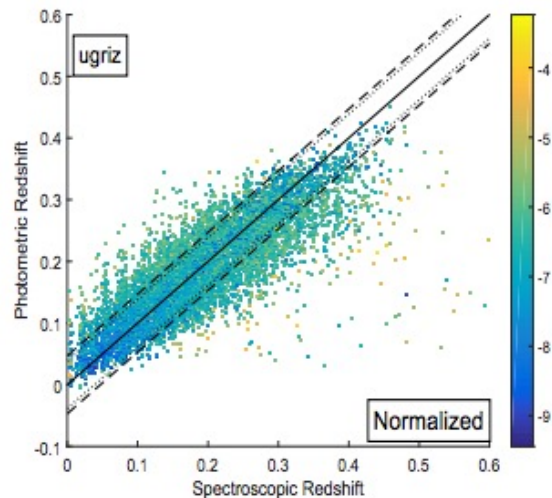
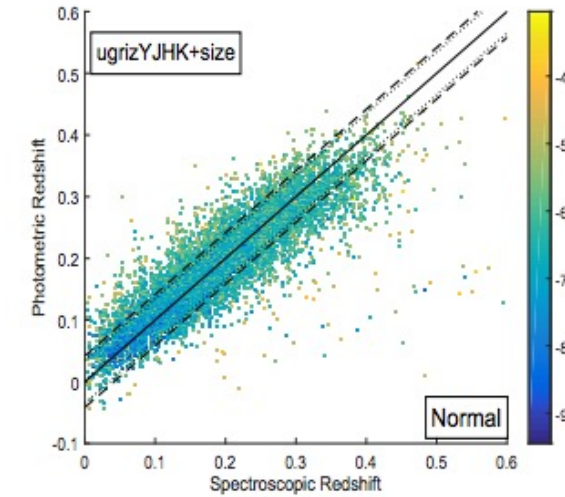
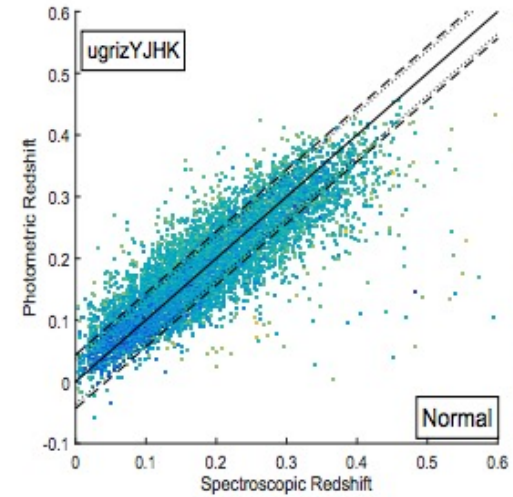
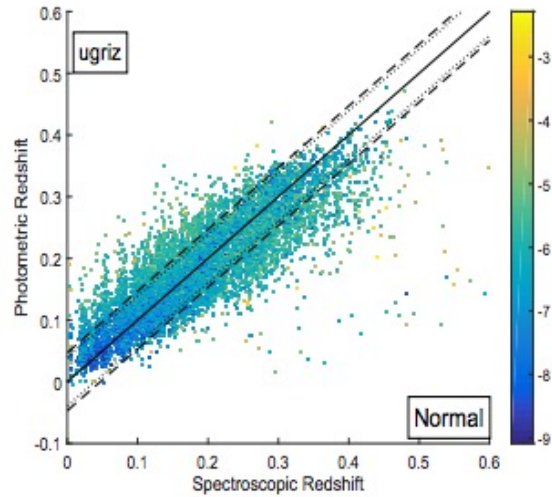
- Confirming method can increase 'effective depth'.
- Still interesting objects in the VISTA data.



Banerji et al. 2015

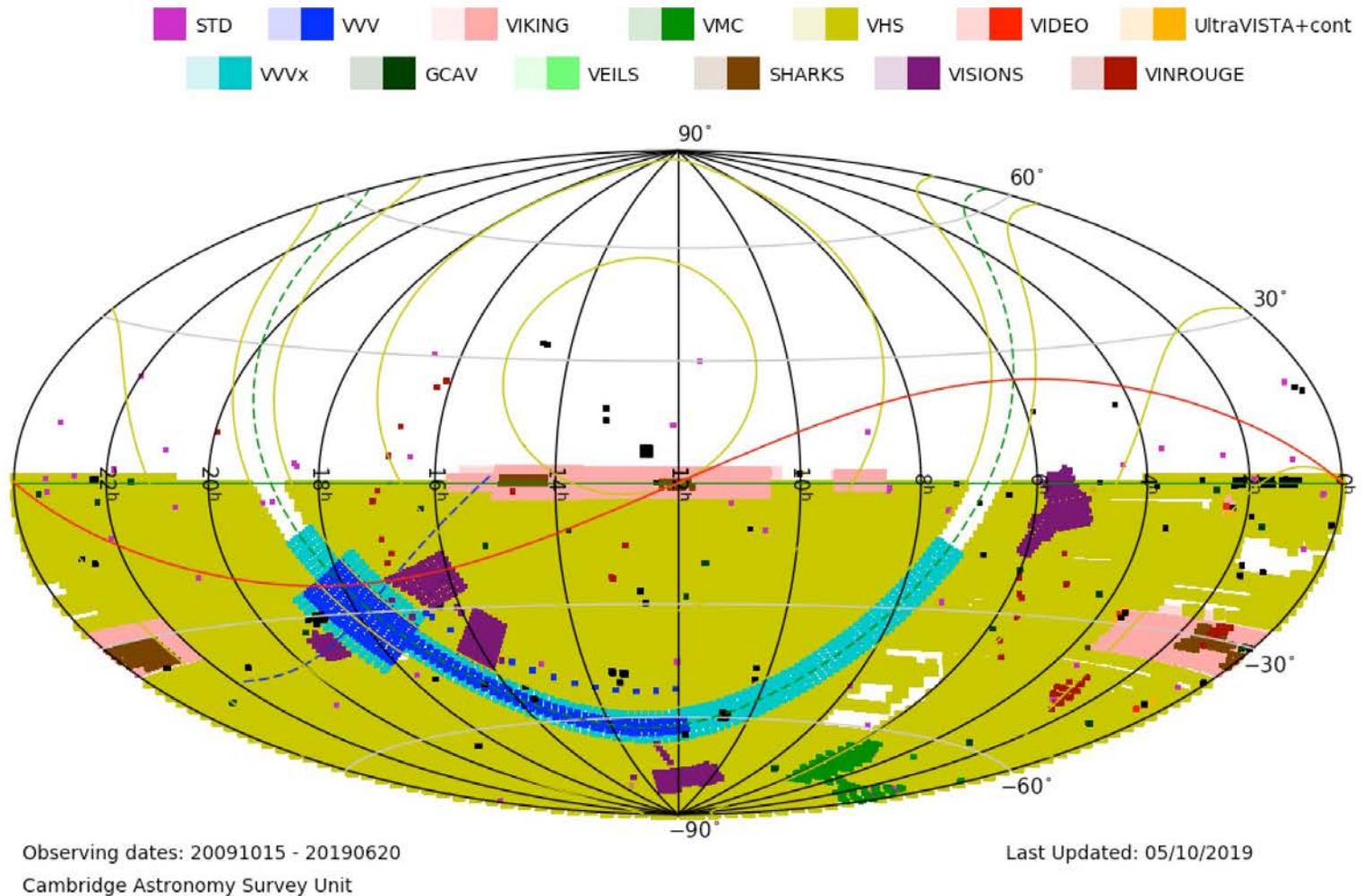
# JHKs contribute to photo-z accuracy

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



# VISTA surveys

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

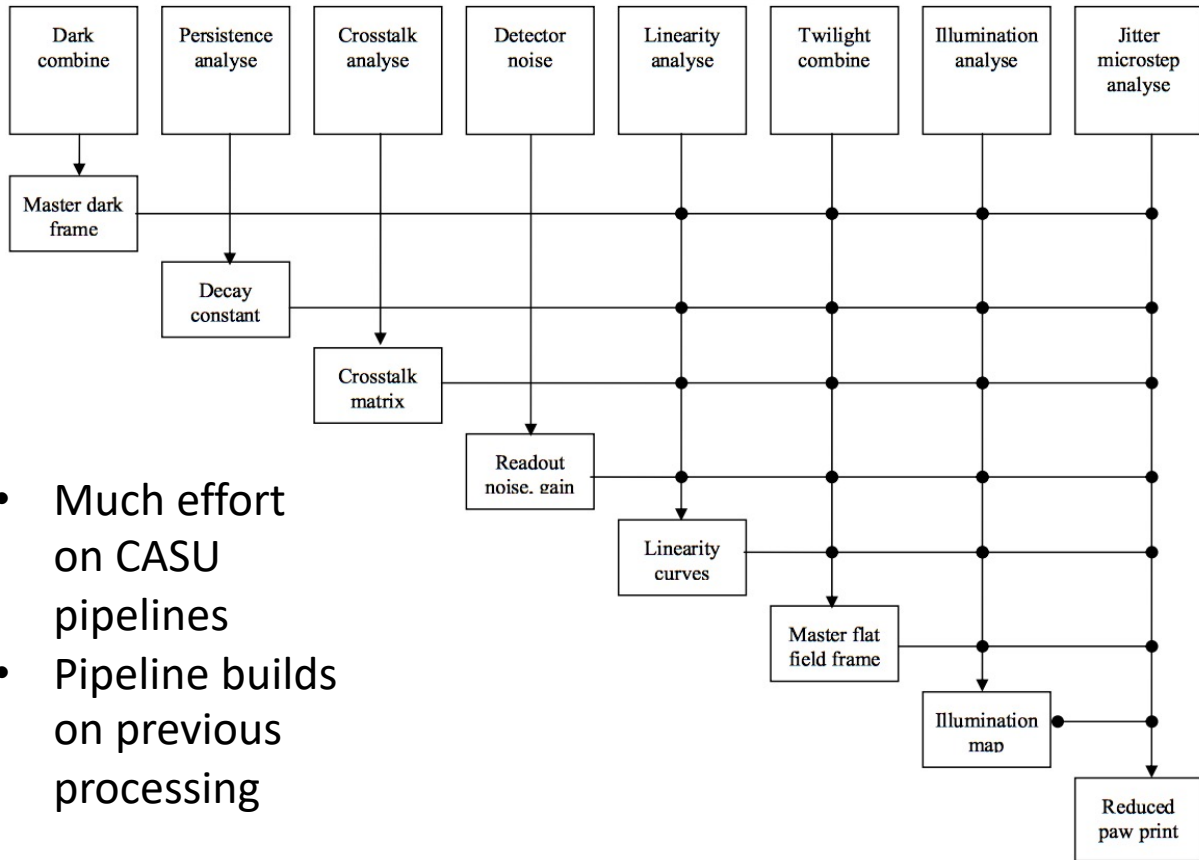




# VISTA survey details

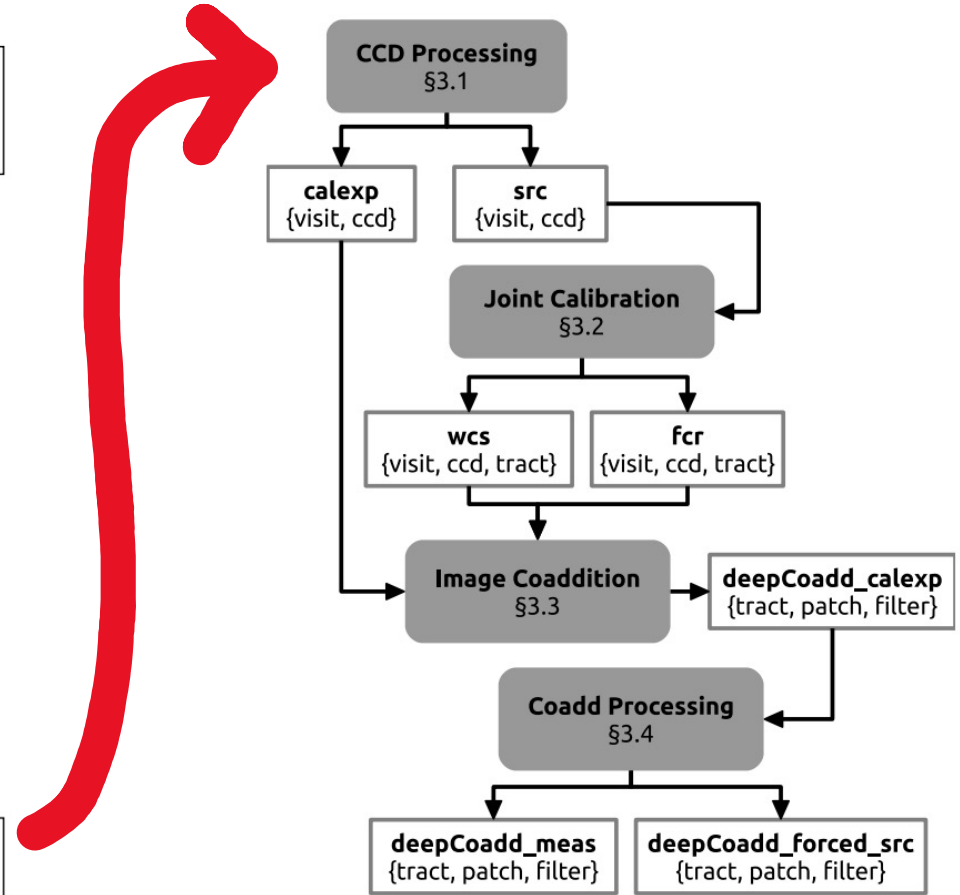
First cycle VISTA surveys						
Acronym	Short Title	PI	Area (deg <sup>2</sup> )	Filters and Depth Measure (mag (10 $\sigma$ , AB))	Depth (mag)	Total number of hrs executed (Nov. 2019)
Ultra-VISTA	An Ultra Deep Survey with VISTA	J. Dunlop	0.73 (ultra-deep)	5 $\sigma$ , AB	Y=26.7 J=26.6 H=26.1 K <sub>s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

# CASU pipeline with LSST science pipelines



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

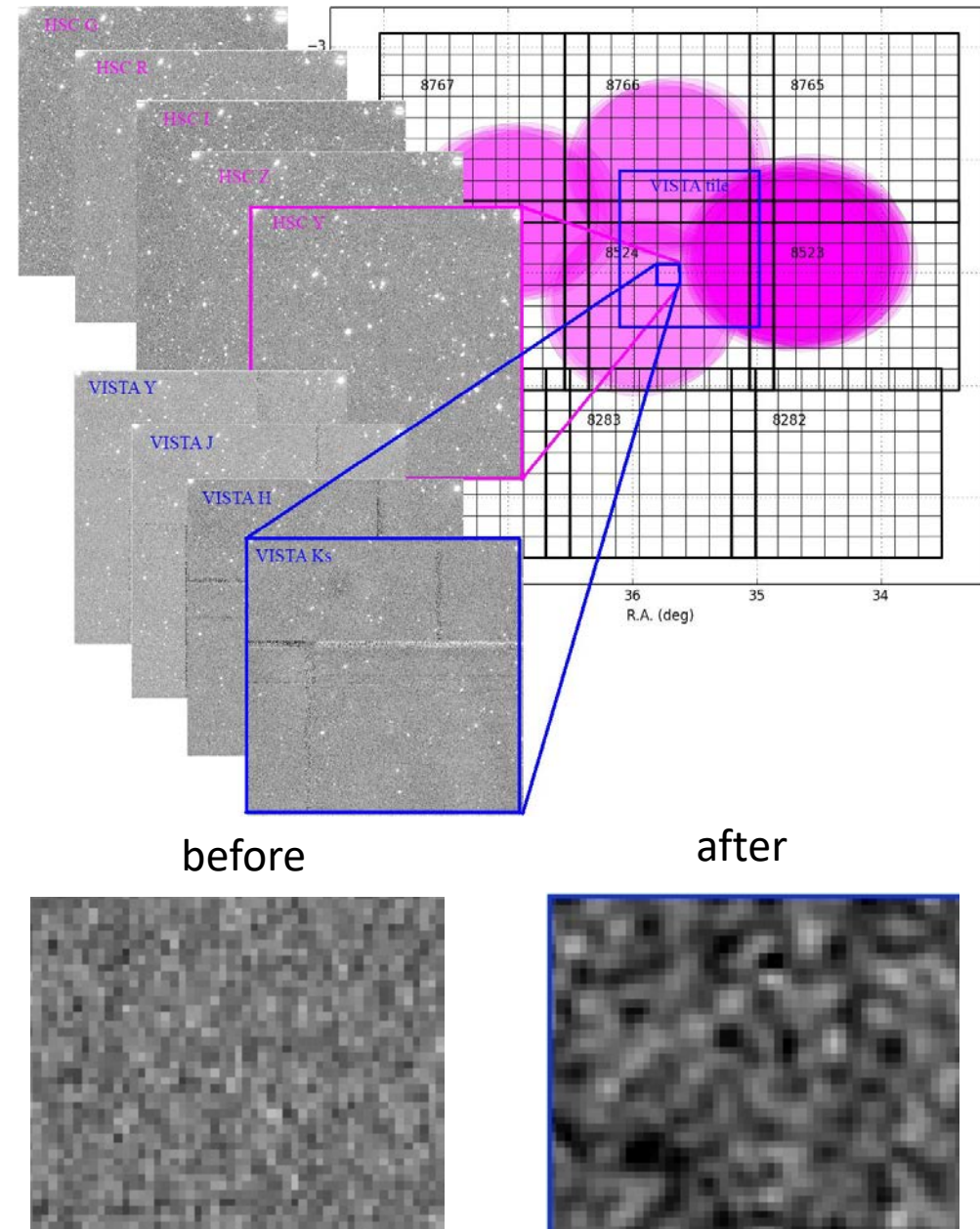
Irwin 1985 ++



Bosch et al. 2018

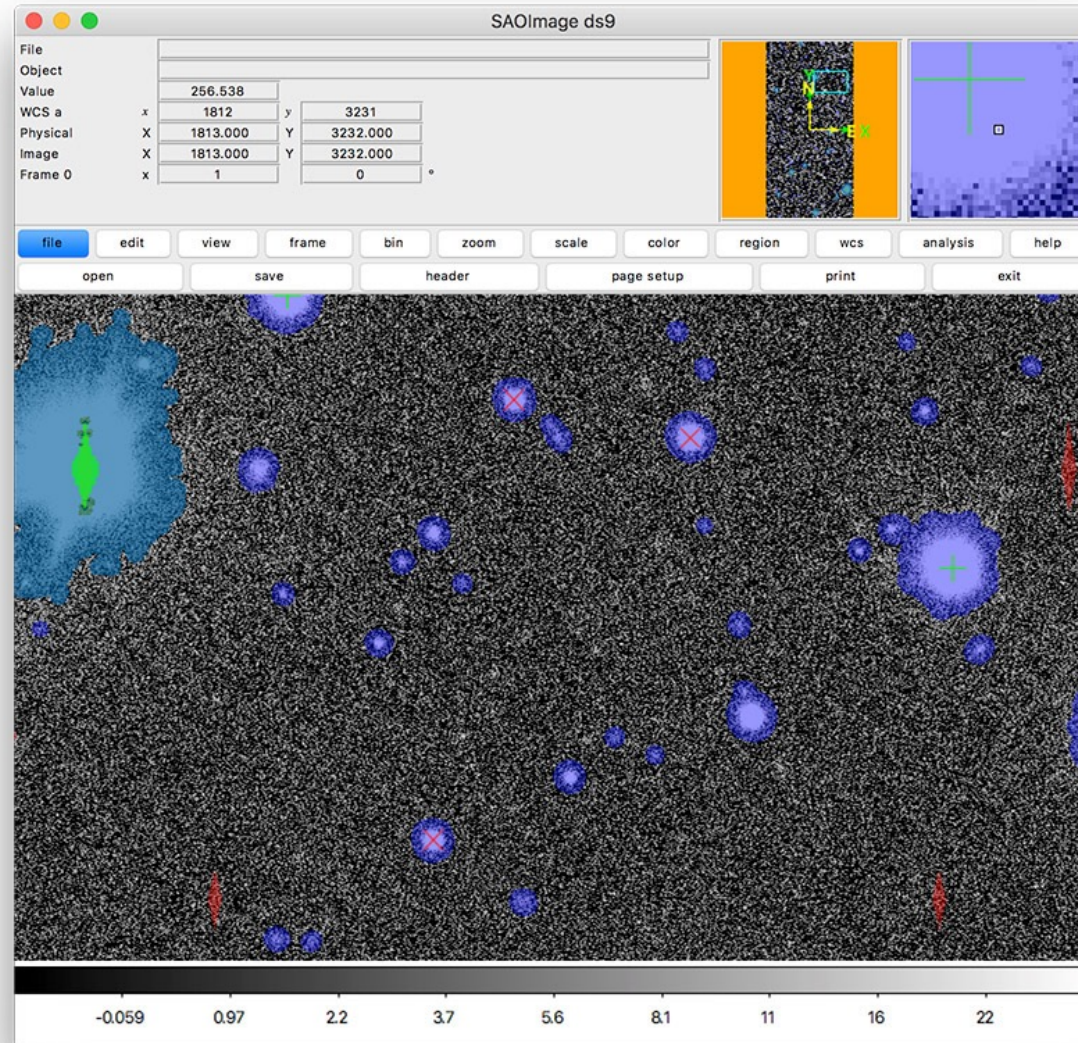
# Warping and coadding

- 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
  - Patches 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

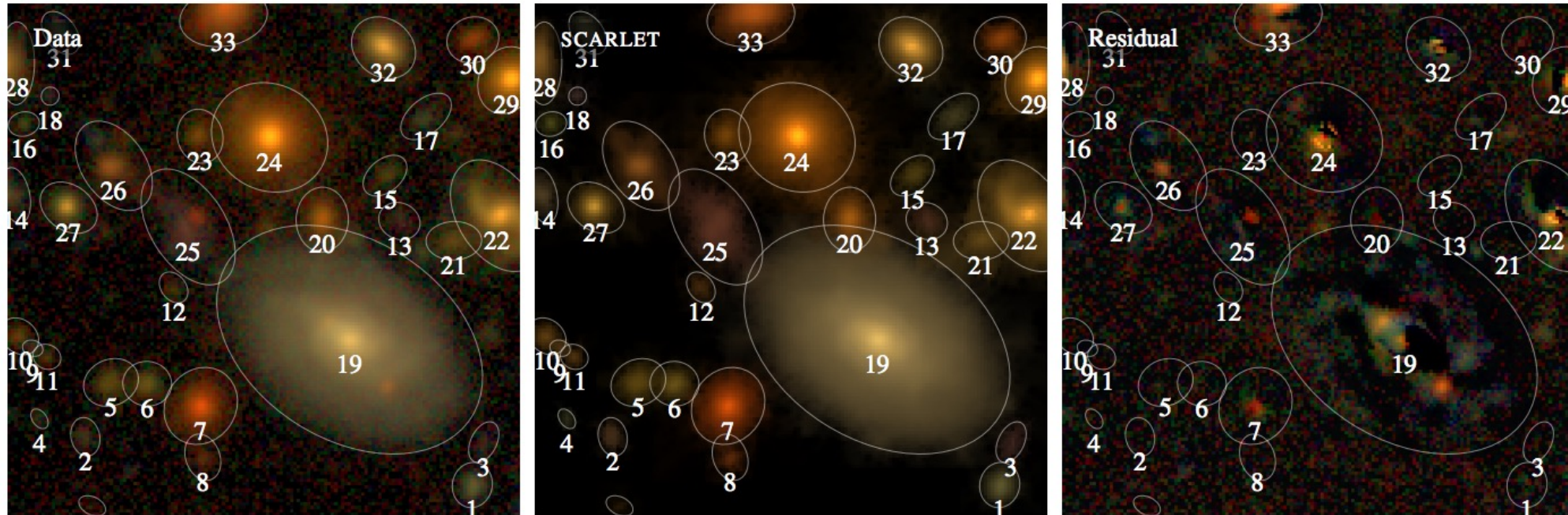


# Photometry

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



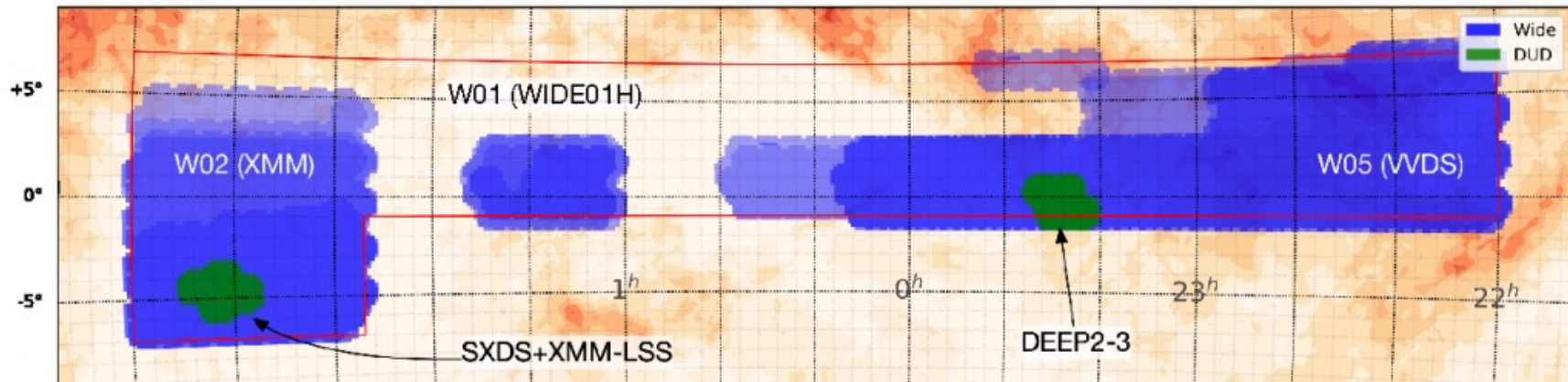
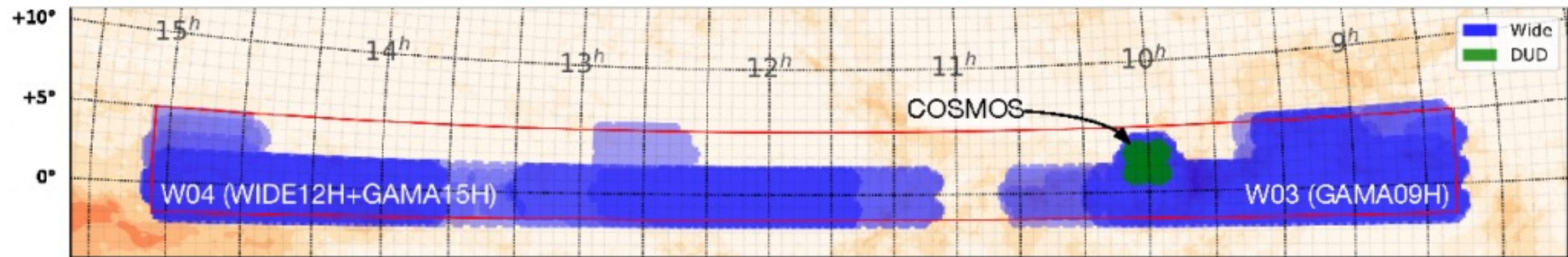
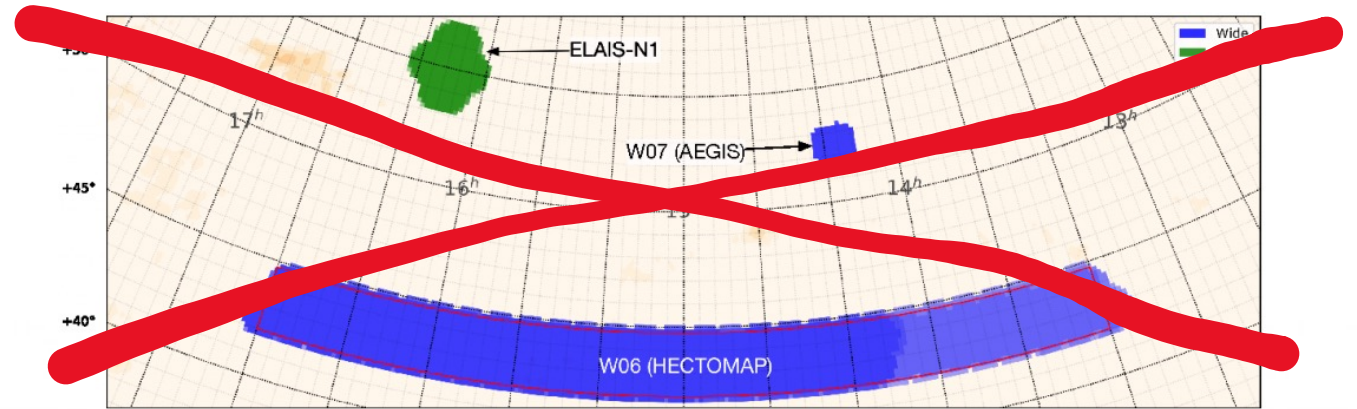
# SCARLET (Melchior et al., 2018)



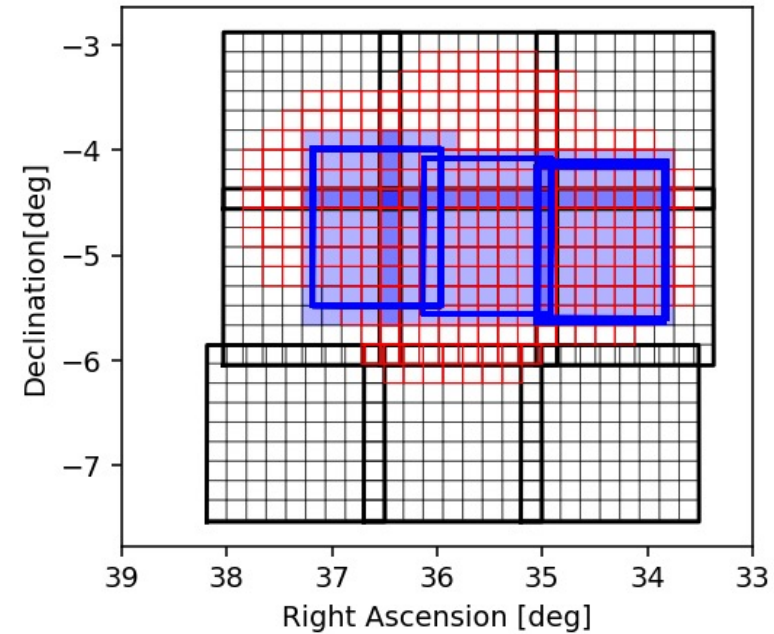
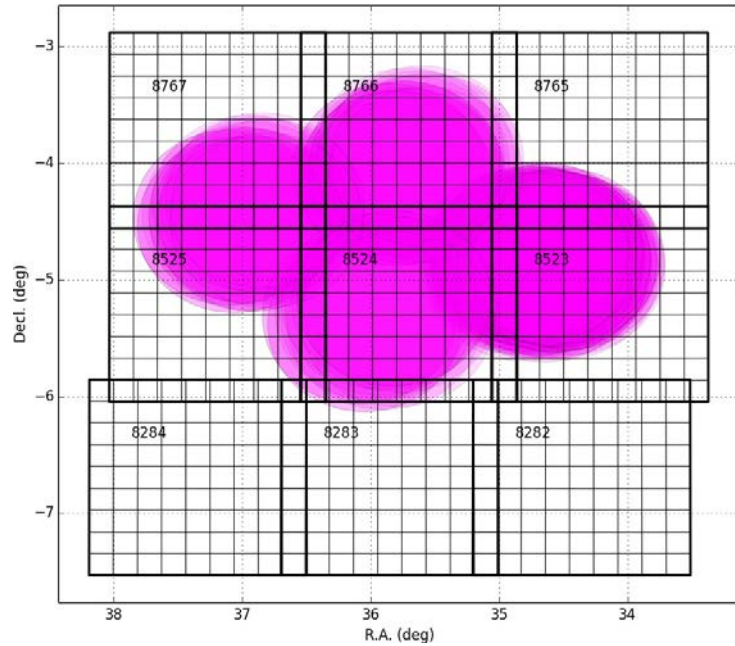
- JHKs adds colour information.
- Working on metrics to understand impact of extra VISTA bands.
- Sub population of objects where VISTA particularly helpful.

# HSC overlap

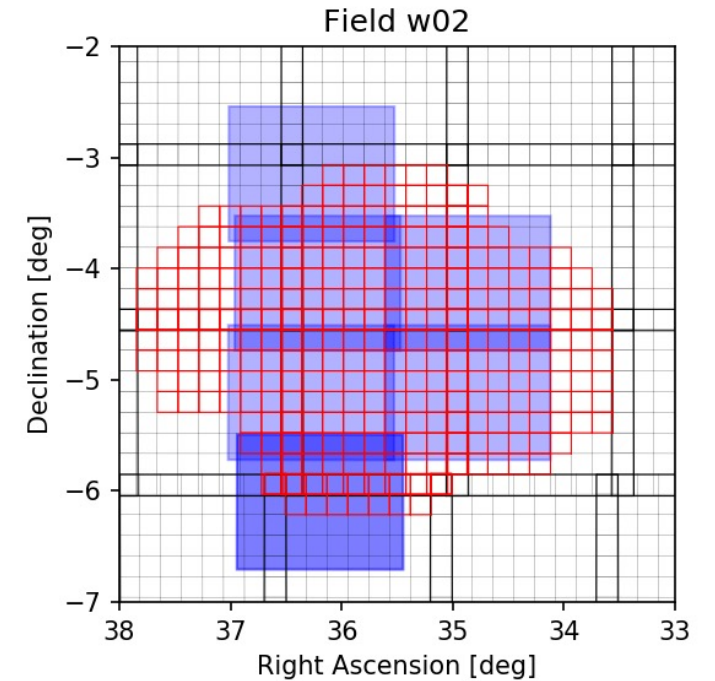
~800 square degrees processing area  
~300 tracts, each  $9 \times 9 = 81$  patches.



# HSC DUD SXDS VHS/VIKING/VIDEO test field



VIDEO

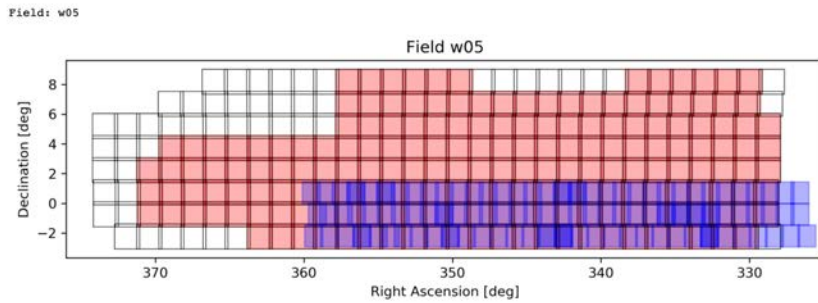
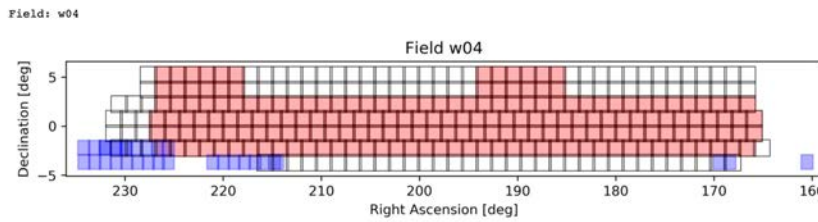
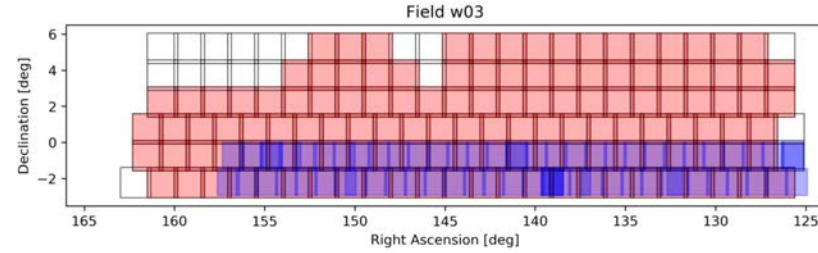
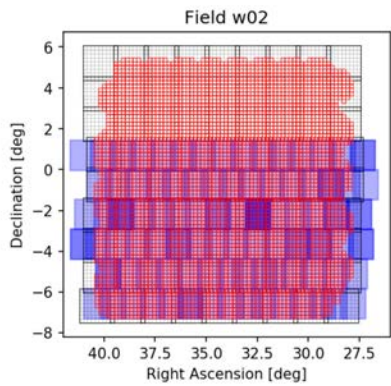
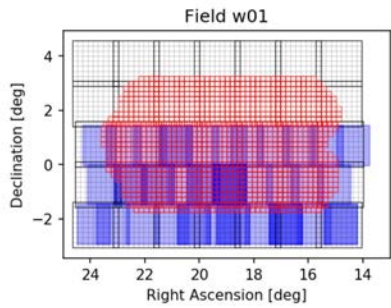


VIKING

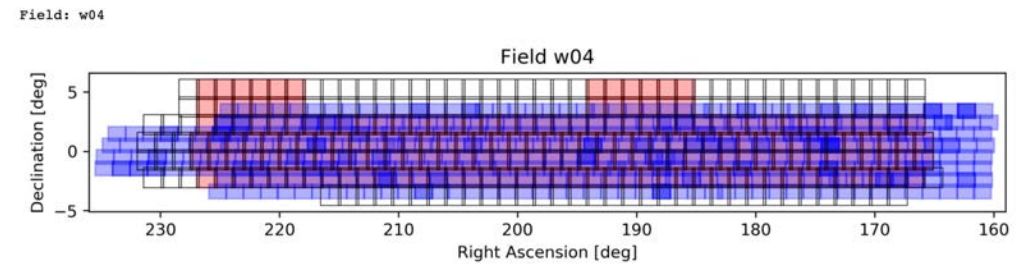
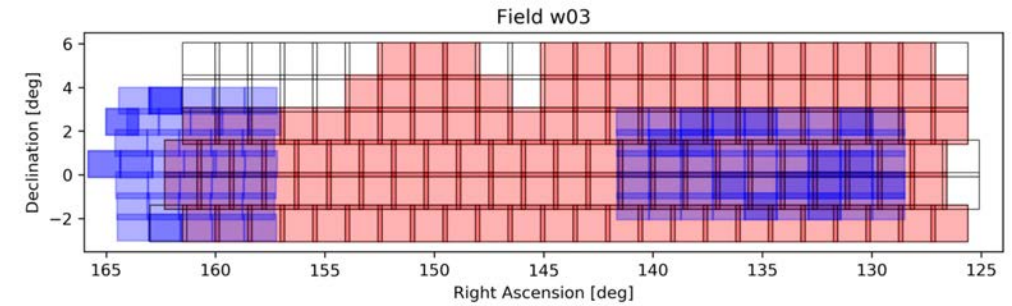
Pink: HSC r pointings, red: HSC patches, blue: VHS tile pointings

# Full overlap with HSC PDR2

## VHS

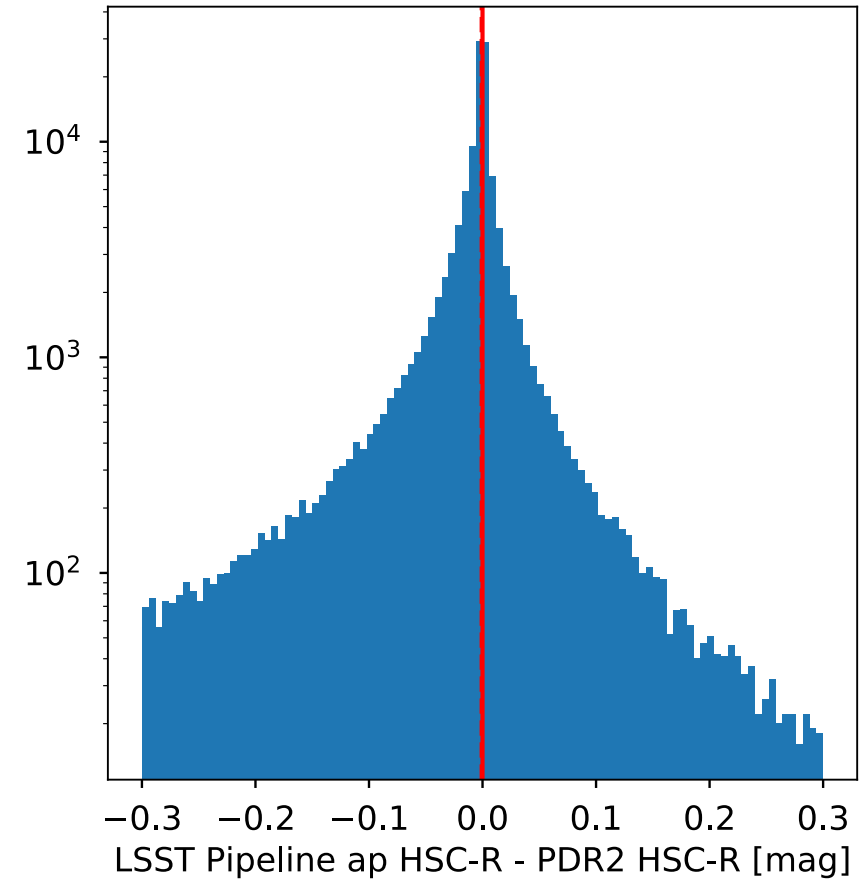
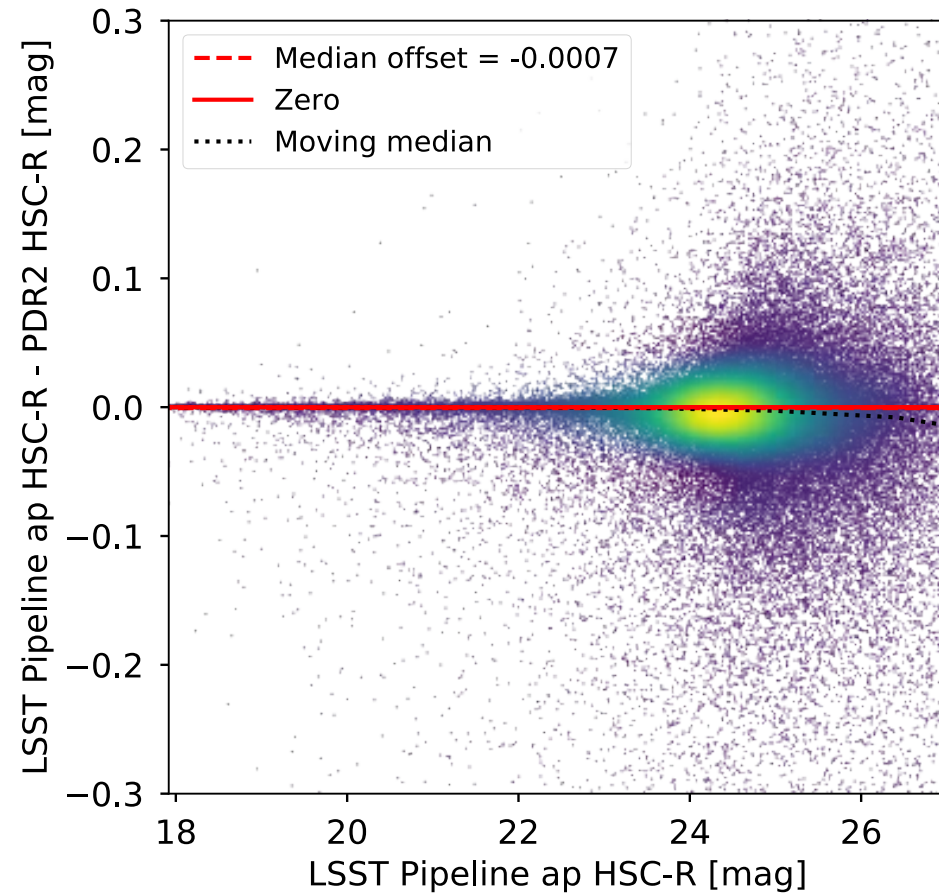


## VIKING

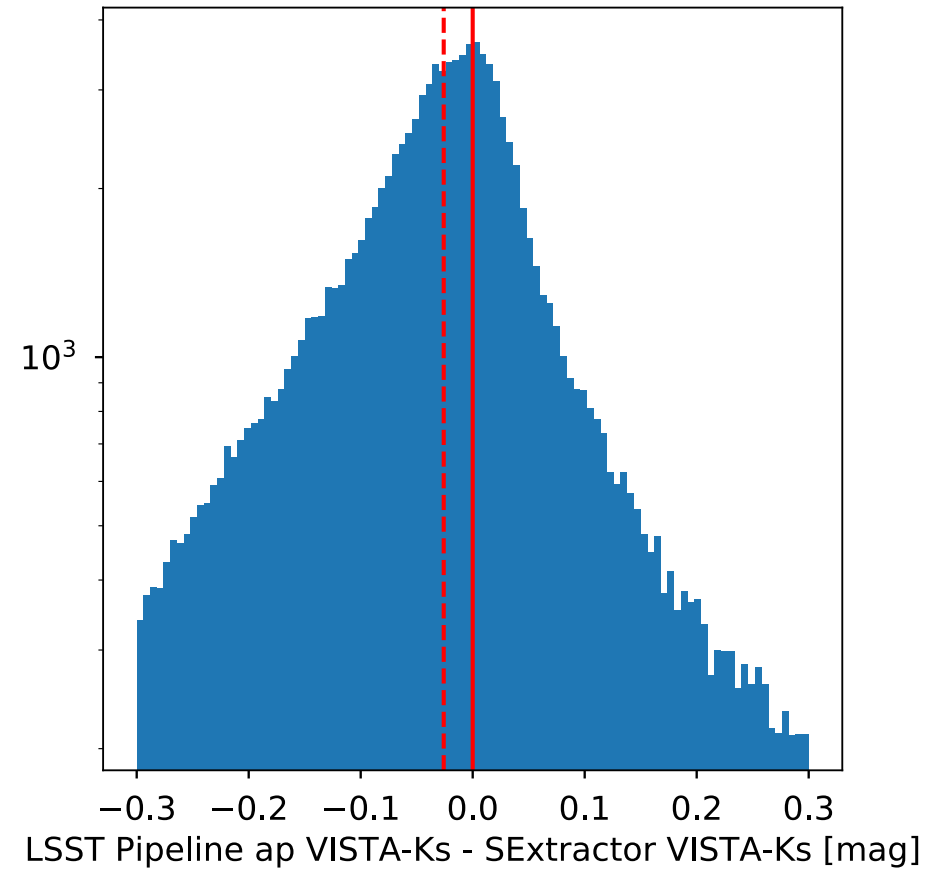
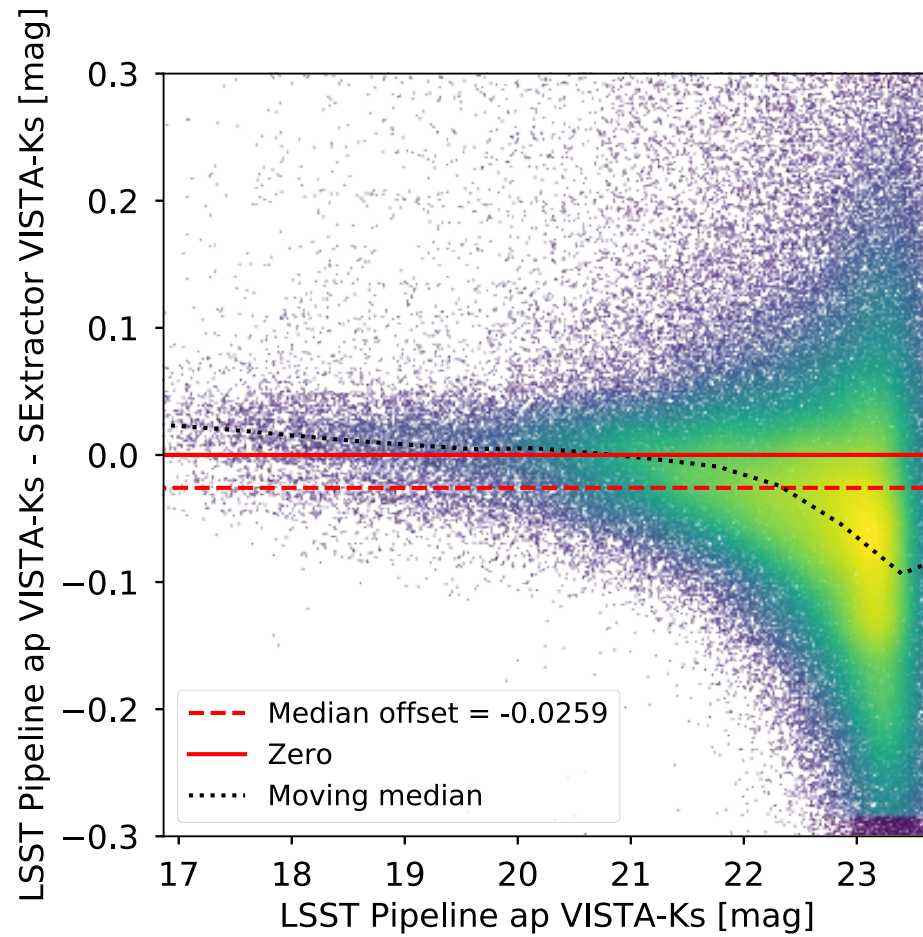




# Quality control

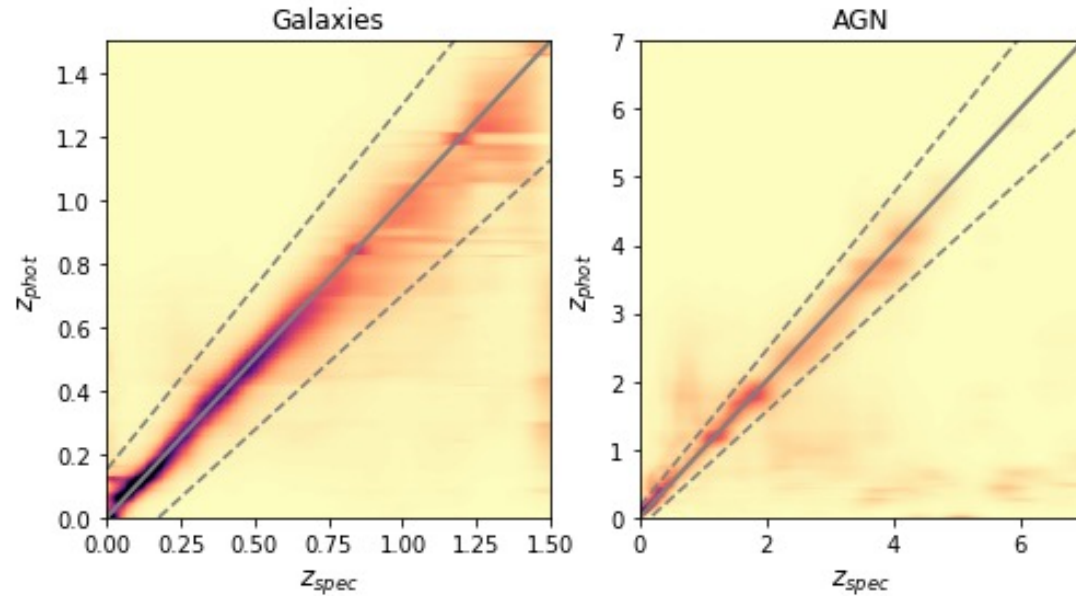


# Quality control



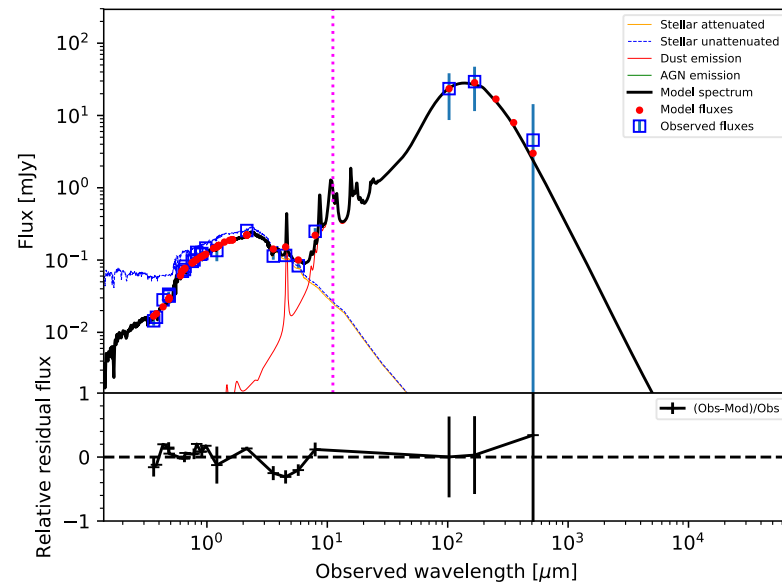
# Scientific tests

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



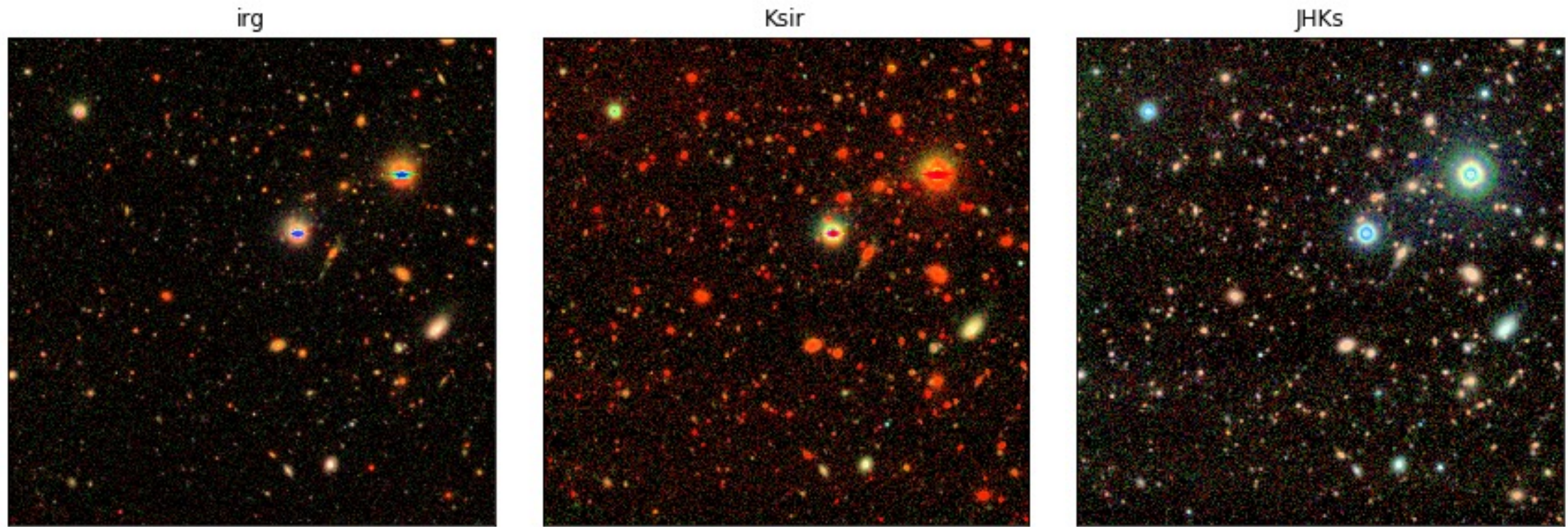
Dunken et al. 2018

Best model for HELP\_J141620.719+522333.580 at  $z = 0.391$   $\chi^2=1.88$   
OPT $\chi^2=2.15$  IR $\chi^2=0.12$  threshold (OPT IR)=11.13 [ $\mu\text{m}$ ]



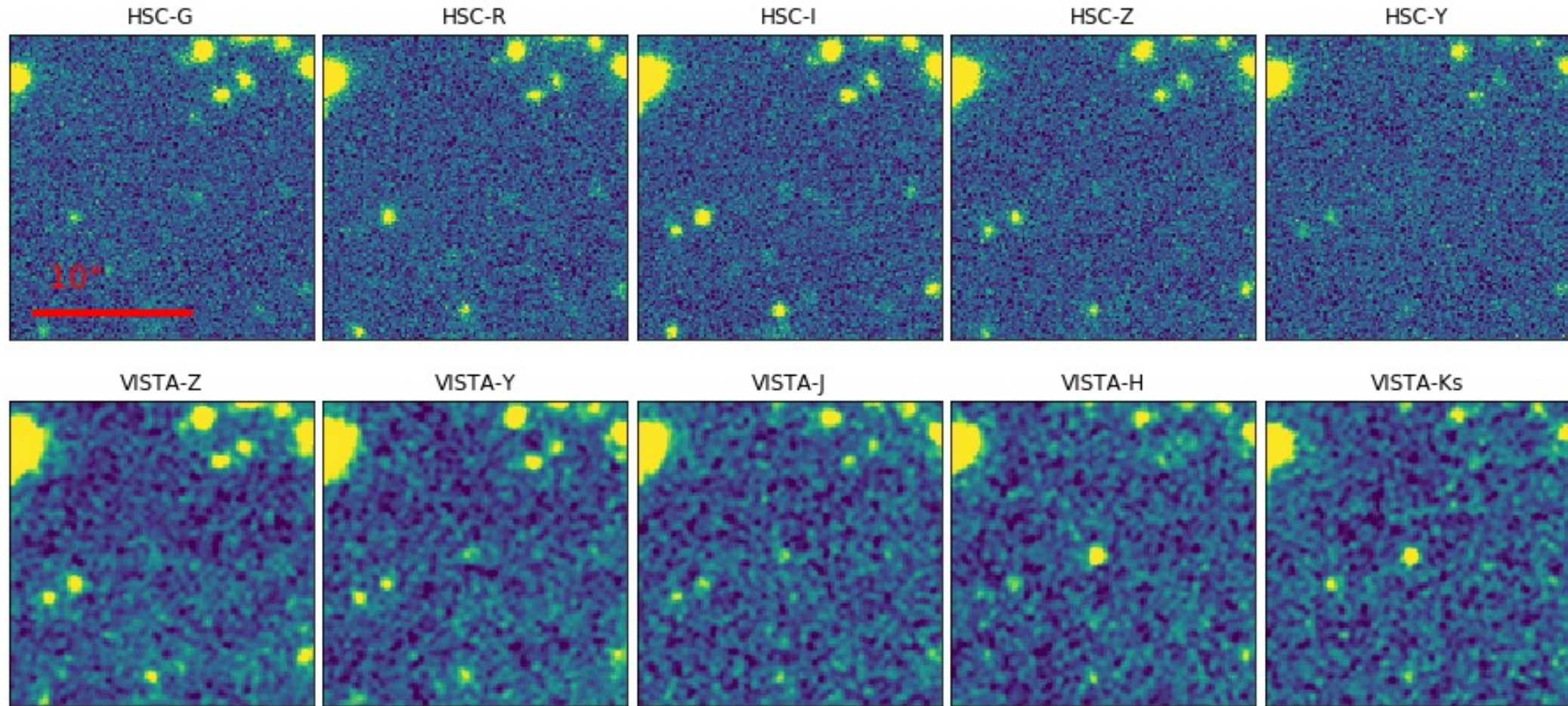
Małek et al. 2018,  
Riccio et al. (in proc)

# Example 1, Cluster $z \sim 1.8$



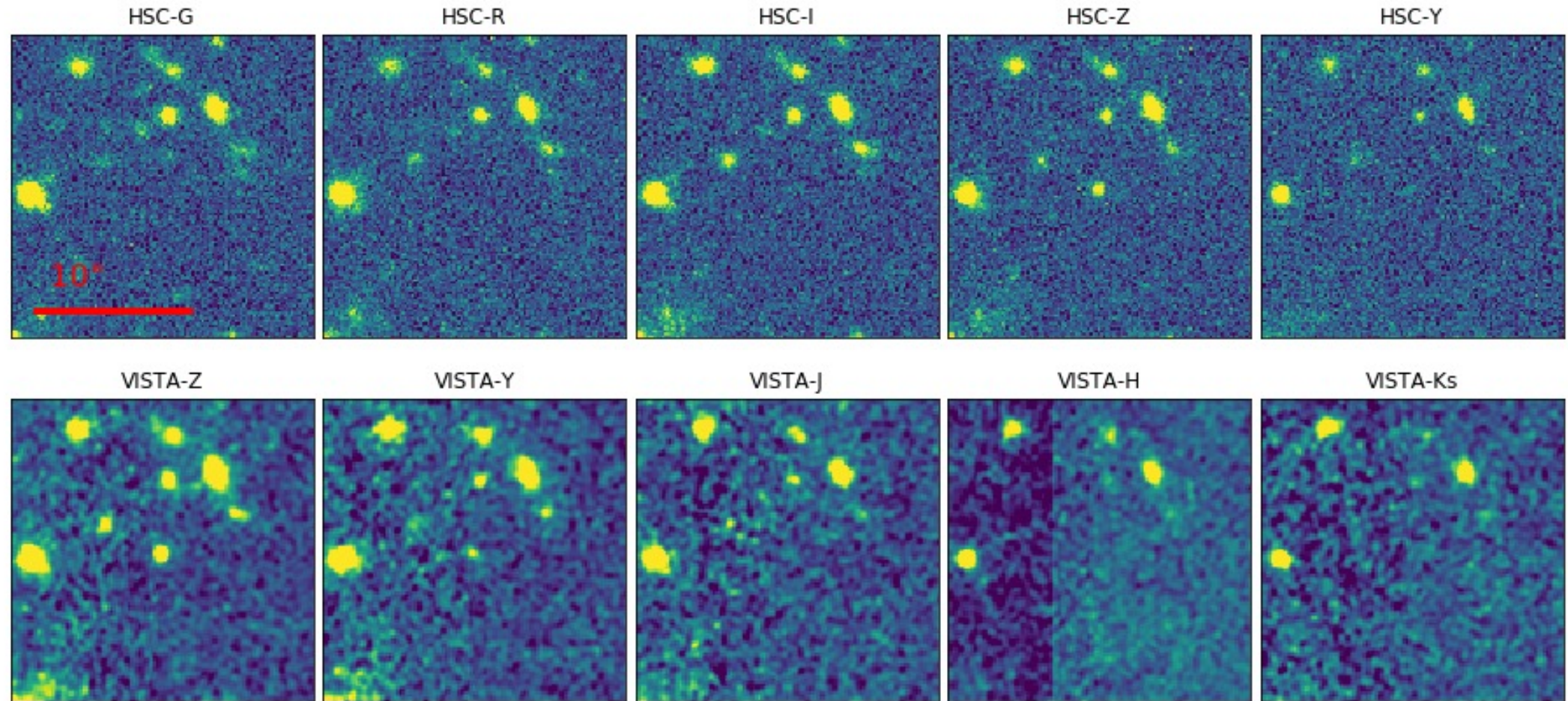
Andreon et al. (2018) JKCS 041: a Coma cluster progenitor at  $z = 1.803$

# Example 2, Extremely red object, $z \sim 2.5$



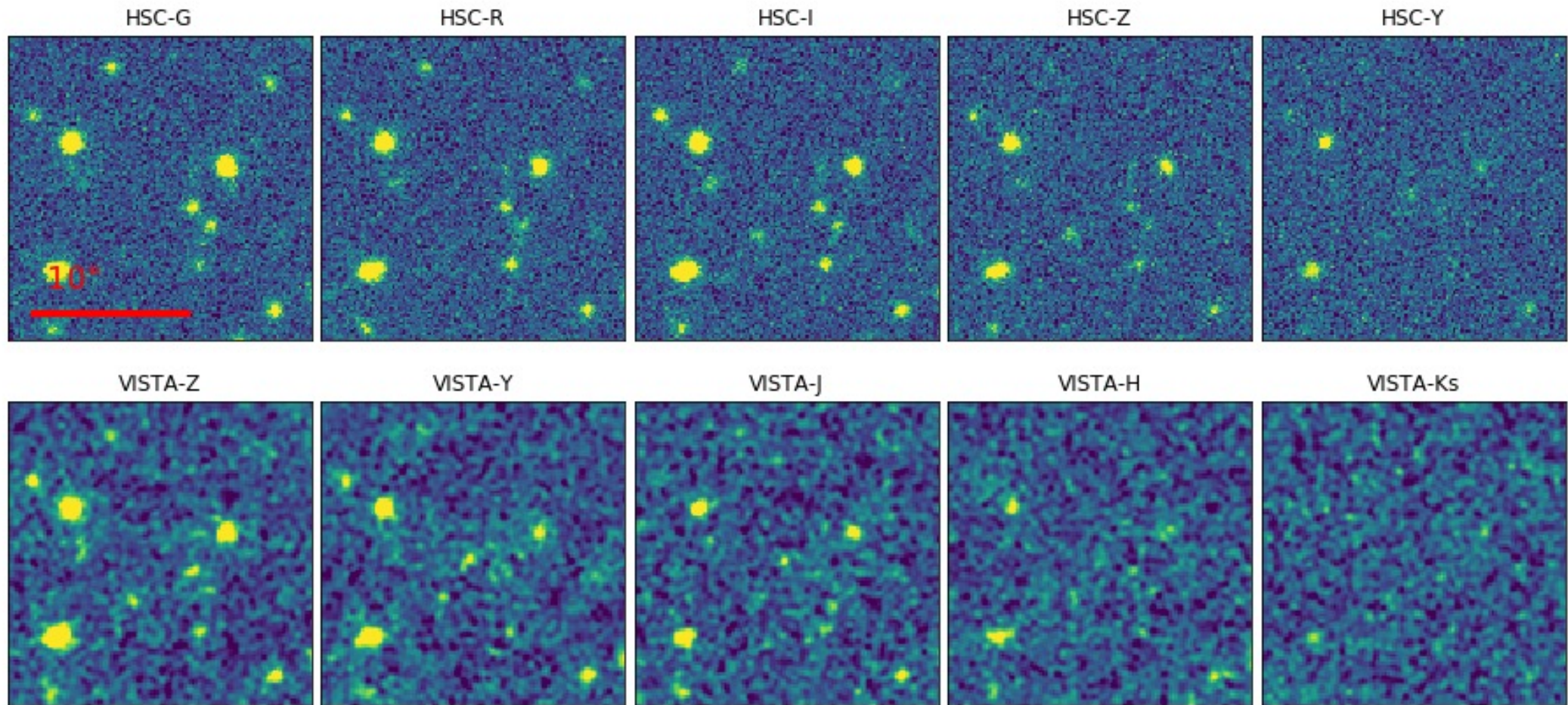
Candidate passive galaxies and/or very dusty star-forming galaxies/AGN  
from Castro-Rodriguez et al. (2018)

# Example 3, redshift 6 quasar



Wilott et al. (2010)

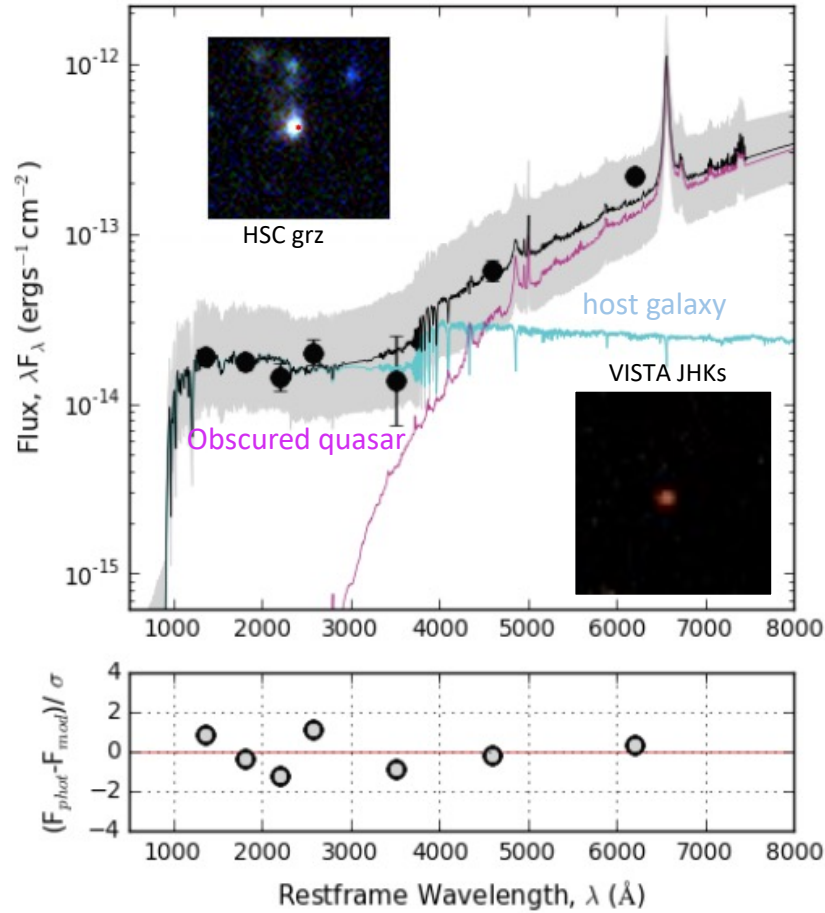
# Example 4, LBG $6.5 < \text{photoz} < 7.5$



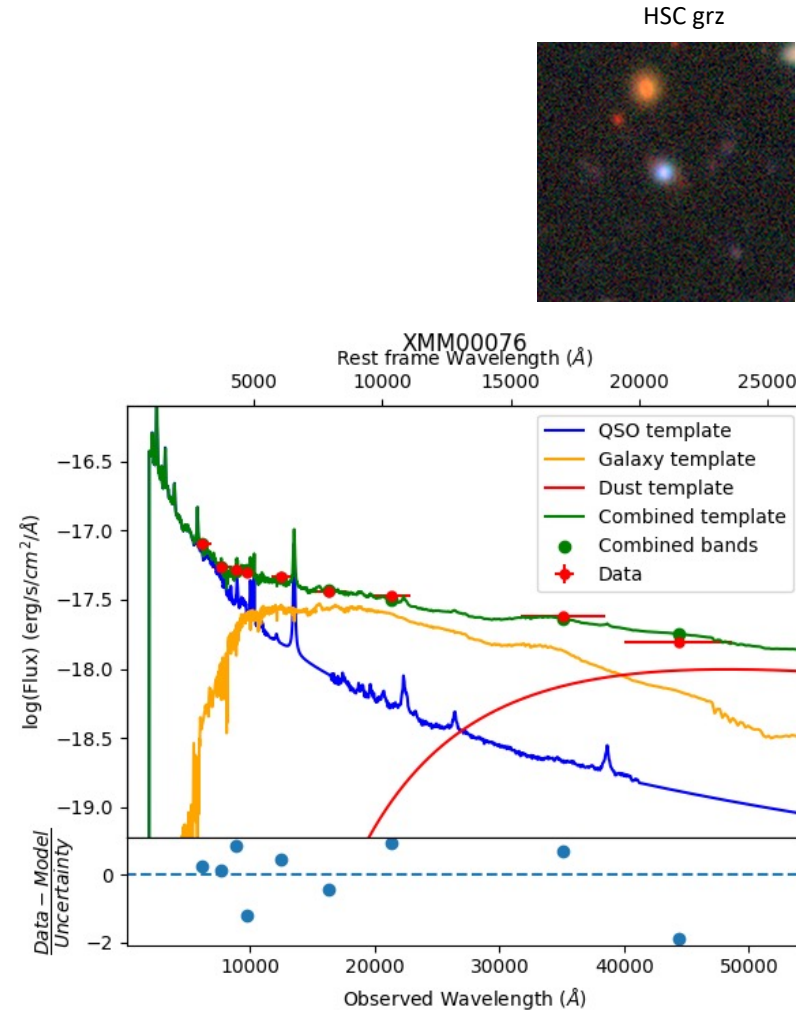
Bowler et al. (2014, 2016)

# AGN Host Galaxies, 2 examples

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



Wethers+18, Banerji+21



Marshall+ in prep

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



# Conclusions

- Aperture matched photometry from Rubin *ugrizy* and VISTA *ZYJHKs*.
- XMM-SXDS HSC prototype produced and testing started.
- Full VIDEO, VHS, VIKING HSC Wide overlap imminent.
- Essentially all of Wide Fast Deep LSST survey covered by VHS.
- Everything in place for first datasets at start of operations. Continuous development alongside commissioning.
- All code is public.