

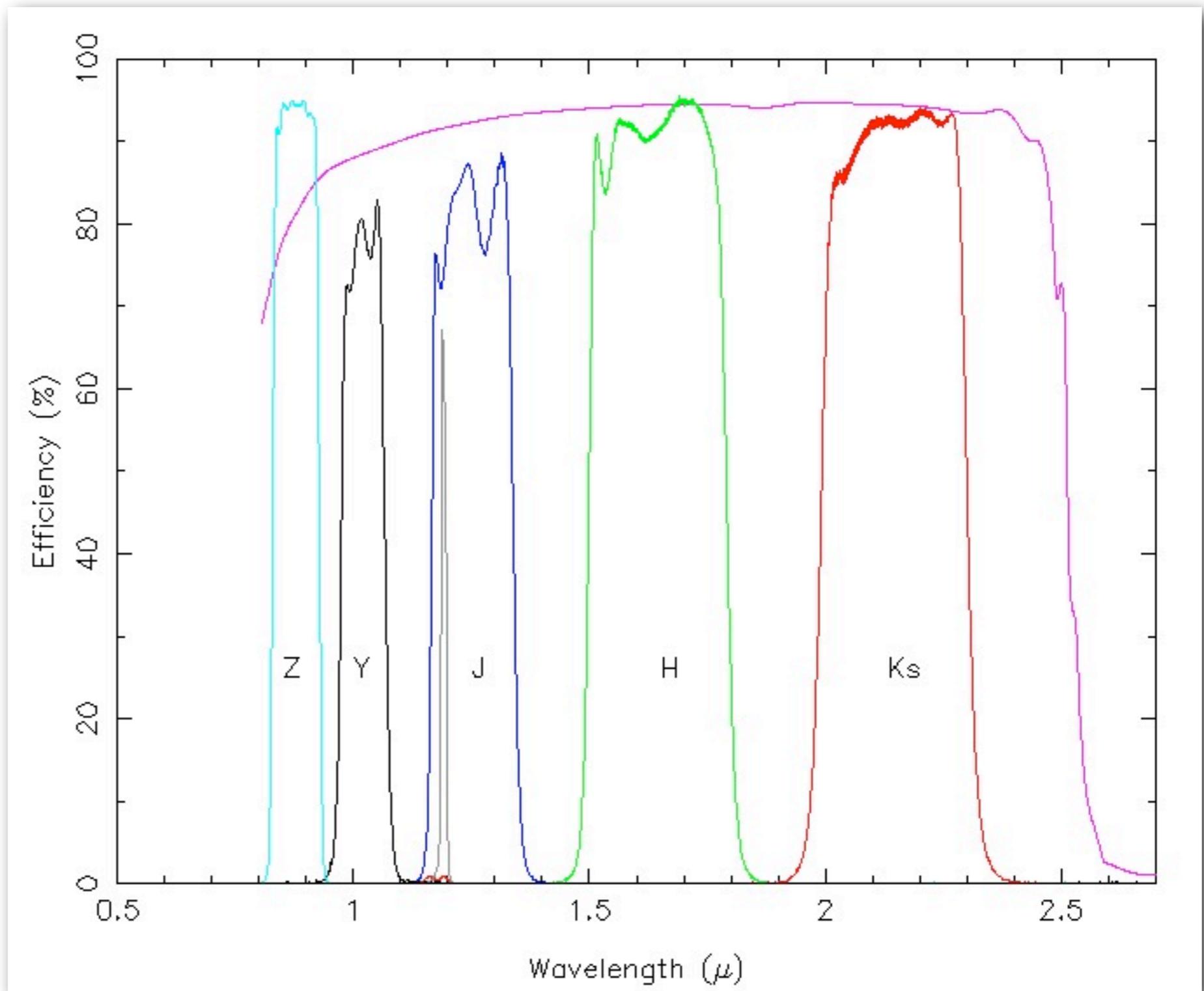
# Photometric Calibration of VISTA

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<http://casu.ast.cam.ac.uk/surveys-projects/vista/technical>

# Filters and QE



	Z	Y	J	H	Ks	1.18μm
Central Wavelength (μm)	0.877	1.020	1.252	1.645	2.147	1.191
Width (μm)	0.097	0.093	0.172	0.291	0.309	0.011
Effective Wavelength(μm)	0.878	1.021	1.254	1.646	2.149	1.191
Vega to AB	0.521	0.618	0.937	1.384	1.839	0.853

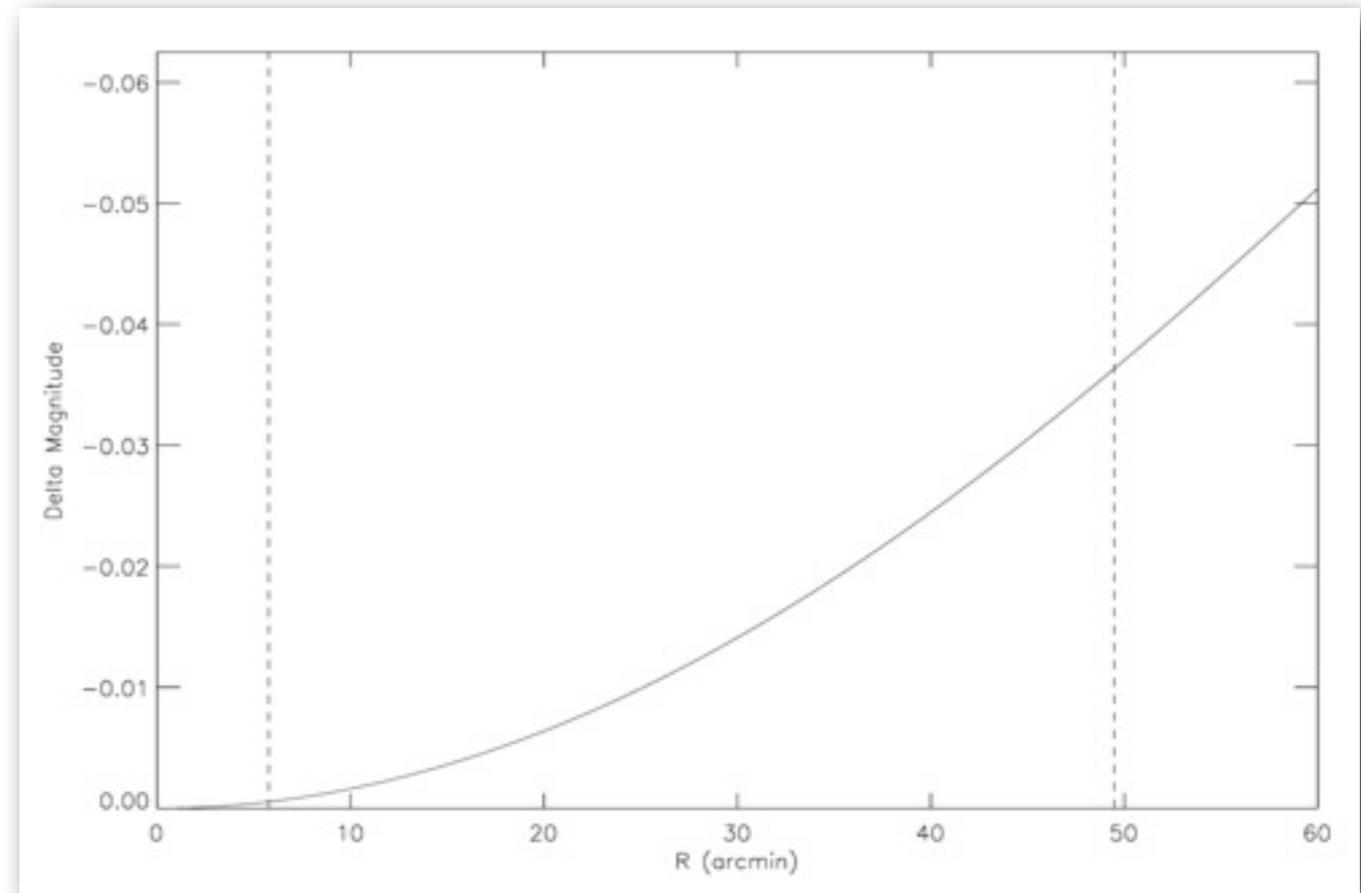
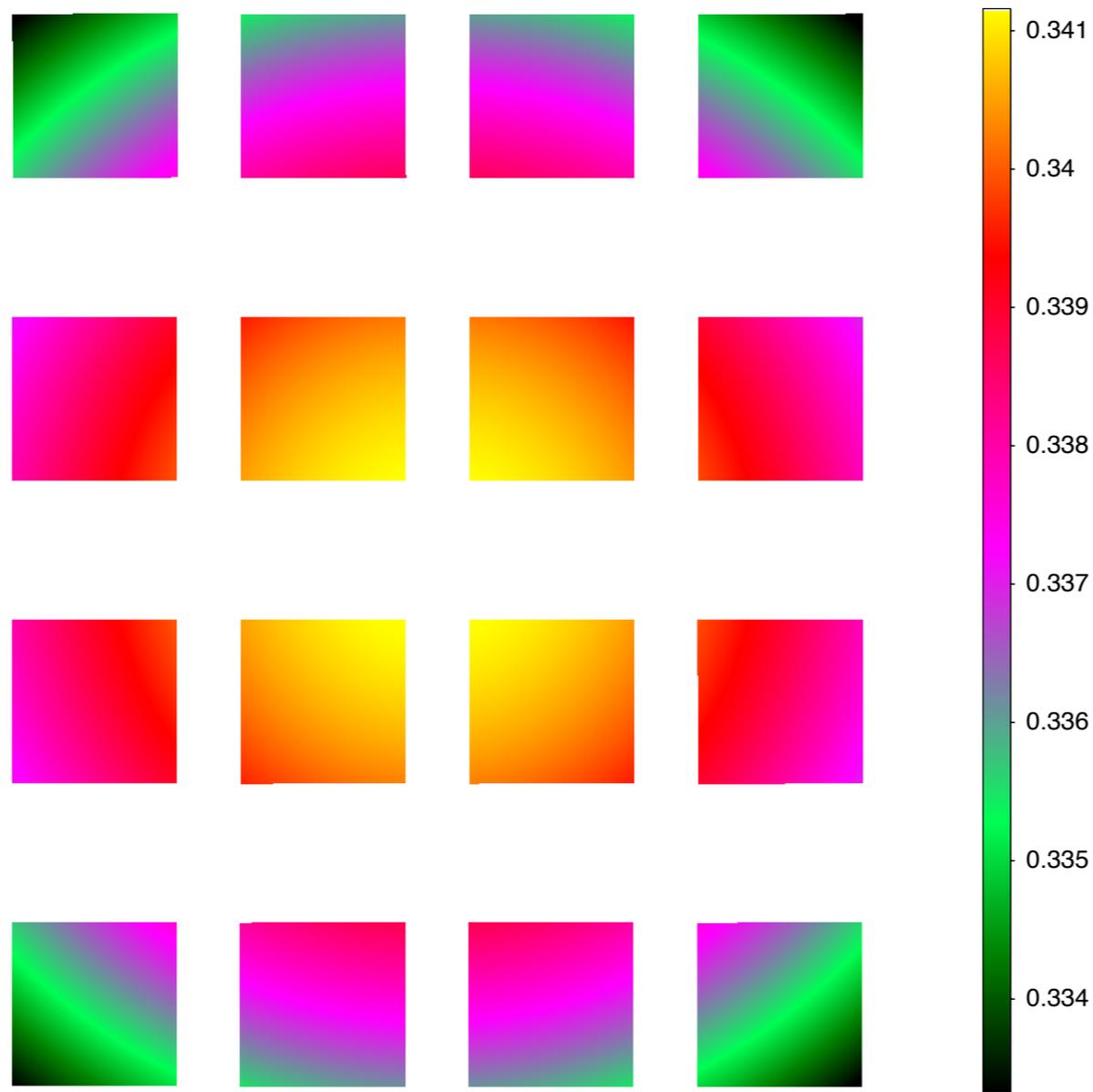
# motivation

- The VHS requirement is to photometrically calibrate VIRCAM data to 2%
- 2MASS is globally consistent to  $\sim 1\%$  photometry
- WFCAM processing has used 2MASS to calibrate the JHK photometry to 1.5% and ZY to 2% (Hodgkin et al. 2009)
- Calibration stars observed at the same time and under the same conditions
- Overheads reduced and surveys progress faster
- Can recover photometric calibration even during non-photometric conditions

# method

- start from the aperture corrected (distortion corrected) instrumental mags:  $-2.5\log(\text{distortcor}*\text{flux})$
- each science image contains a large number of 2MASS stars  $\text{SNR}_{\text{JHK}} > 10$  and  $0 < \text{J-K} < 1$ .
- Each 2MASS star has its photometry corrected onto the VISTA system using linear colour equations
- we compute a photometric zeropoint,  $\text{ZP}^*$ , for every 2MASS star in the detector, combining to give a detector  $\text{ZP}_{\text{det}}$ . (flatfielding includes an initial gain correction between detectors)

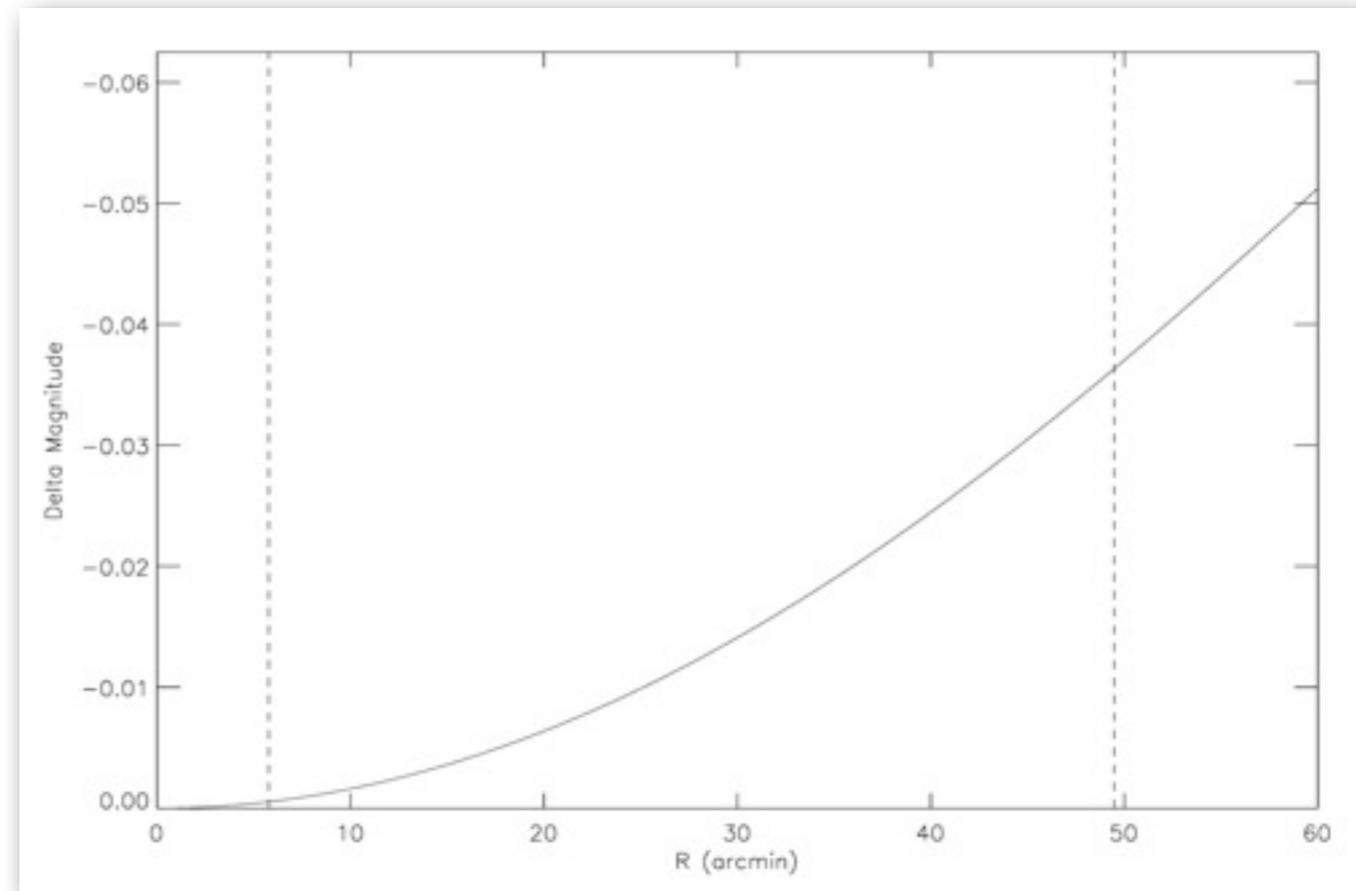
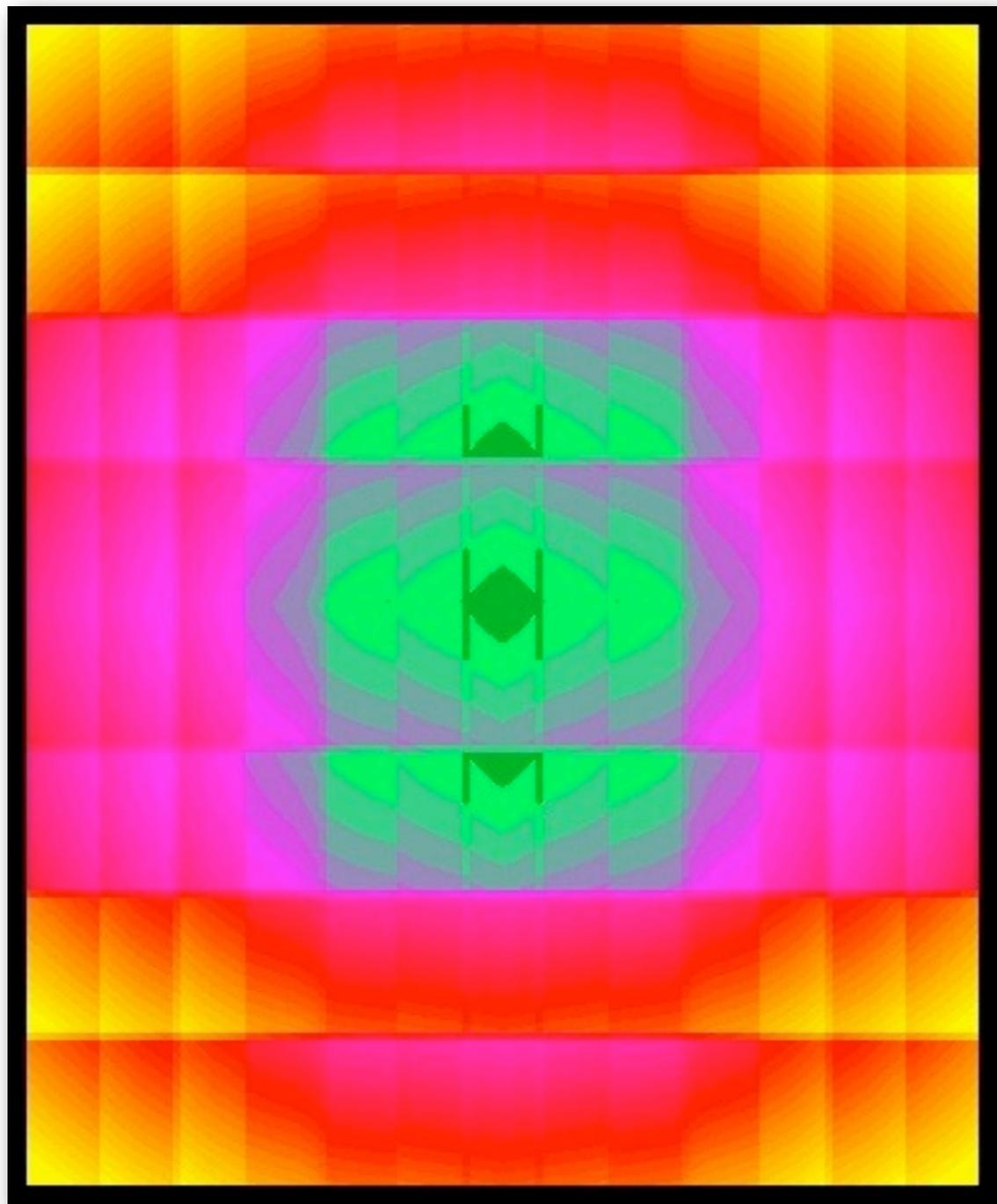
# Variation of pixel scales



Flat fielding introduces a spatially dependent calibration artefact

$$f_{\text{cor}} = f / \left(1 + 3 \frac{k_3}{k_1} r^2 + 5 \frac{k_5}{k_1} r^4\right) \left(1 + \frac{k_3}{k_1} r^2 + \frac{k_5}{k_1} r^4\right)$$

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# method

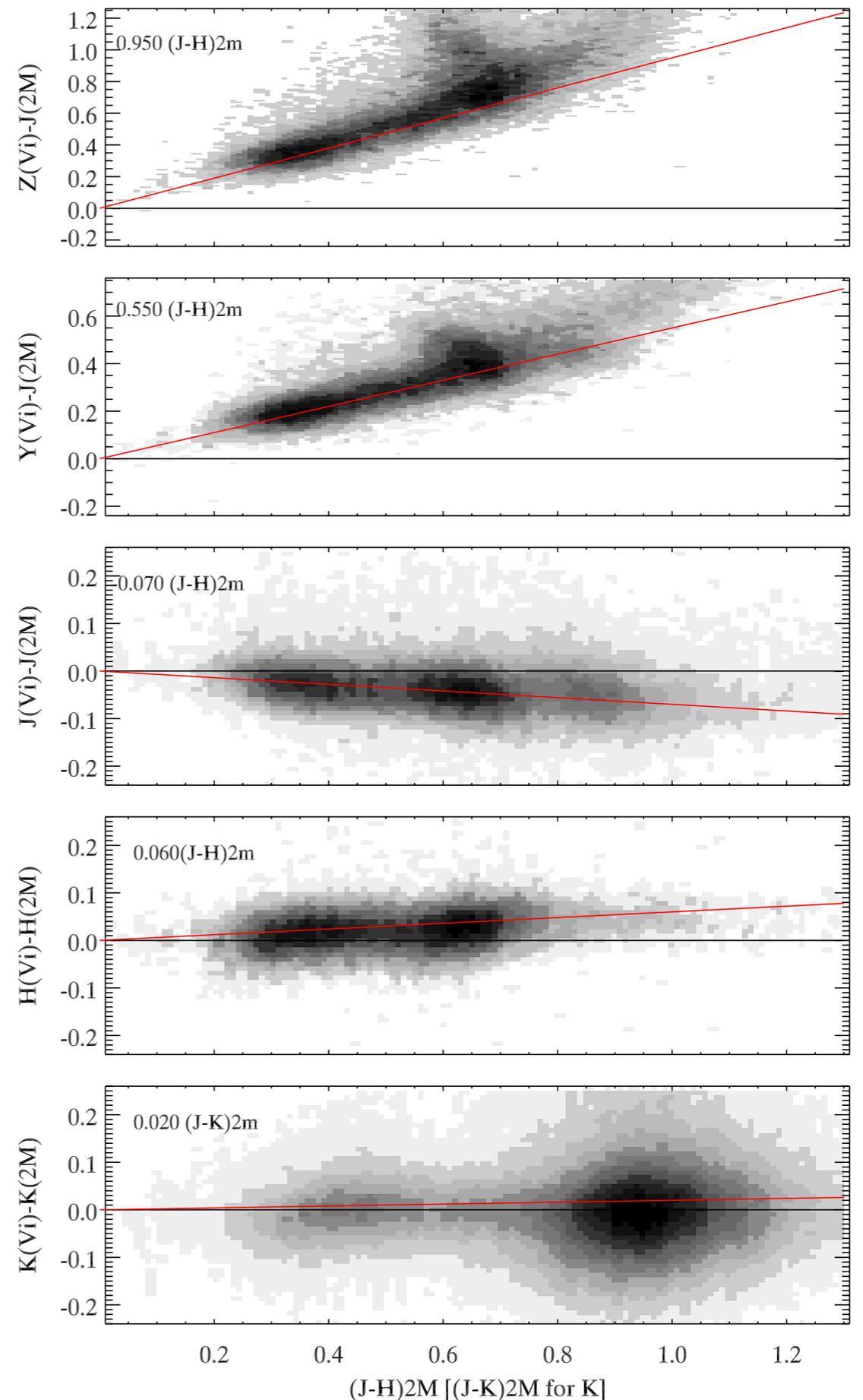
- start from the aperture corrected (distortion corrected) instrumental mags:  $-2.5\log(\text{distortcor}*\text{flux})$
- each science image contains a large number of 2MASS stars  $\text{SNR}_{\text{JHK}} > 10$  and  $0 < \text{J-K} < 1$ .
- Each 2MASS star has its photometry corrected onto the VISTA system using **linear colour equations**
- we compute a photometric zeropoint,  $\text{ZP}^*$ , for every 2MASS star in the detector, combining to give a detector  $\text{ZP}_{\text{det}}$ . (flatfielding includes an initial gain correction between detectors)

# VISTA colour equations

- differences between the VISTA calibrated photometry and the 2MASS magnitudes of matching stars for data taken between June and October.
- star counts are: Z 60k, Y 60k, J 93k, H 39k, Ks 390k.
- the colour indices currently in use are:

$$\begin{aligned} Z_V - J_2 &: 1.025 (J-H)_2 \\ Y_V - J_2 &: 0.610 (J-H)_2 \\ J_V - J_2 &: -0.077 (J-H)_2 \\ H_V - H_2 &: 0.032 (J-H)_2 \\ K_V - K_2 &: 0.010 (J-K)_2 \end{aligned}$$

- for each detector we measure a per-star ZP after correcting the 2MASS photometry onto the VISTA system. [see Hodgkin et al. 2009](#)



# method

- start from the aperture corrected (distortion corrected) instrumental mags:  $-2.5\log(\text{distortcor}*\text{flux})$
- each science image contains a number of 2MASS stars  $\text{SNR}_{\text{JHK}} > 10$  and  $0 < \text{J-K} < 1$ . (97% of pointings have  $> 50$ , median is 150)
- Each 2MASS star has its photometry corrected onto the VISTA system using **linear colour equations including  $E(B-V)$ ' term**
- we compute a photometric zeropoint,  $\text{ZP}_*$ , for every 2MASS star in the detector, combining to give a detector  $\text{ZP}_{\text{det}}$ . (flatfielding includes an initial gain correction between detectors)

# Extinction Correction

- full res Schlegel maps, and interpolate the extinction correction individually for every star used
- Schlegel values are corrected to Bonifacio, Monai & Beers (2000)\*

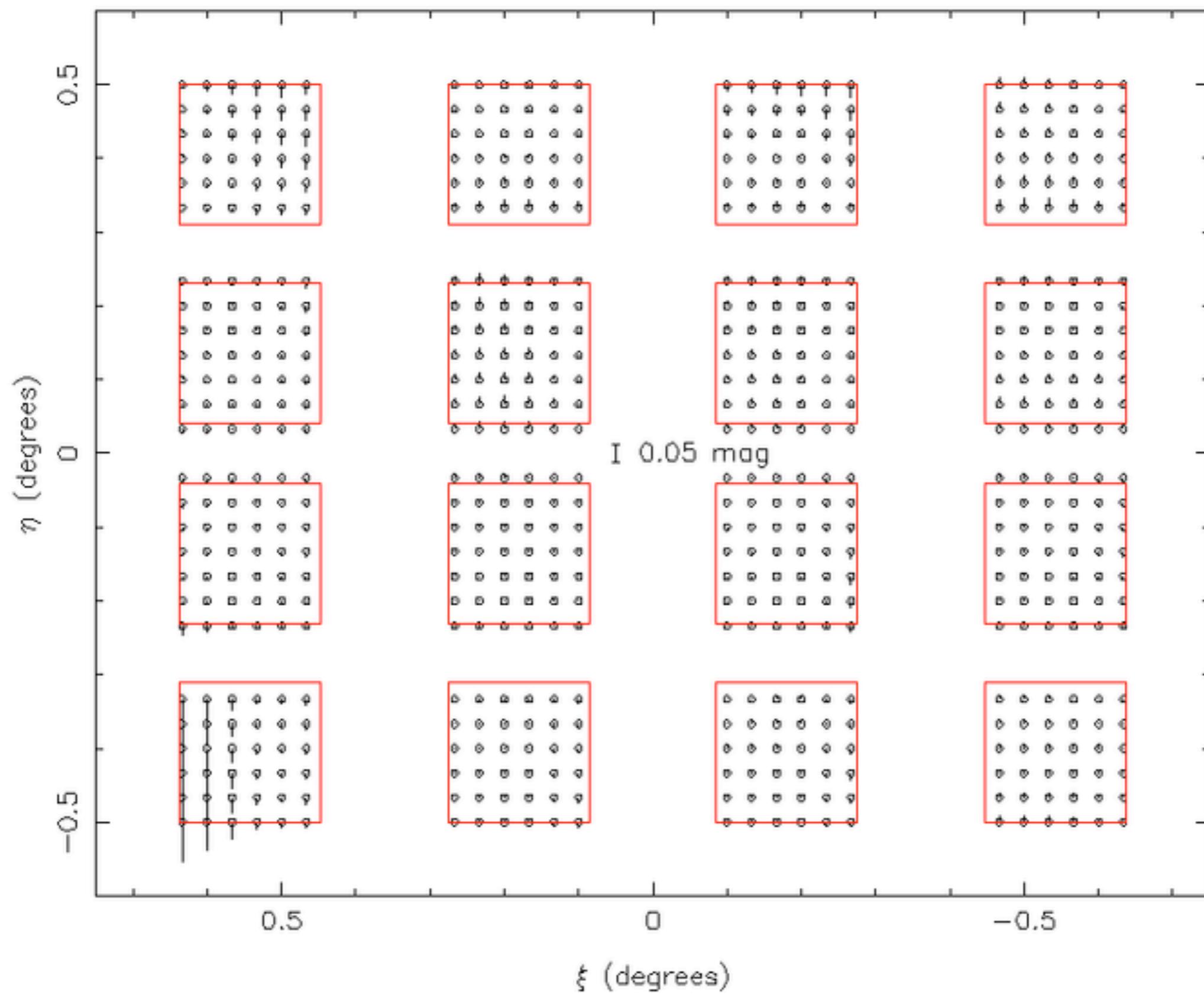
\*if  $E(B-V) > 0.1$  then  $E(B-V) = 0.1 + 0.65 * [E(B-V) - 0.1]$

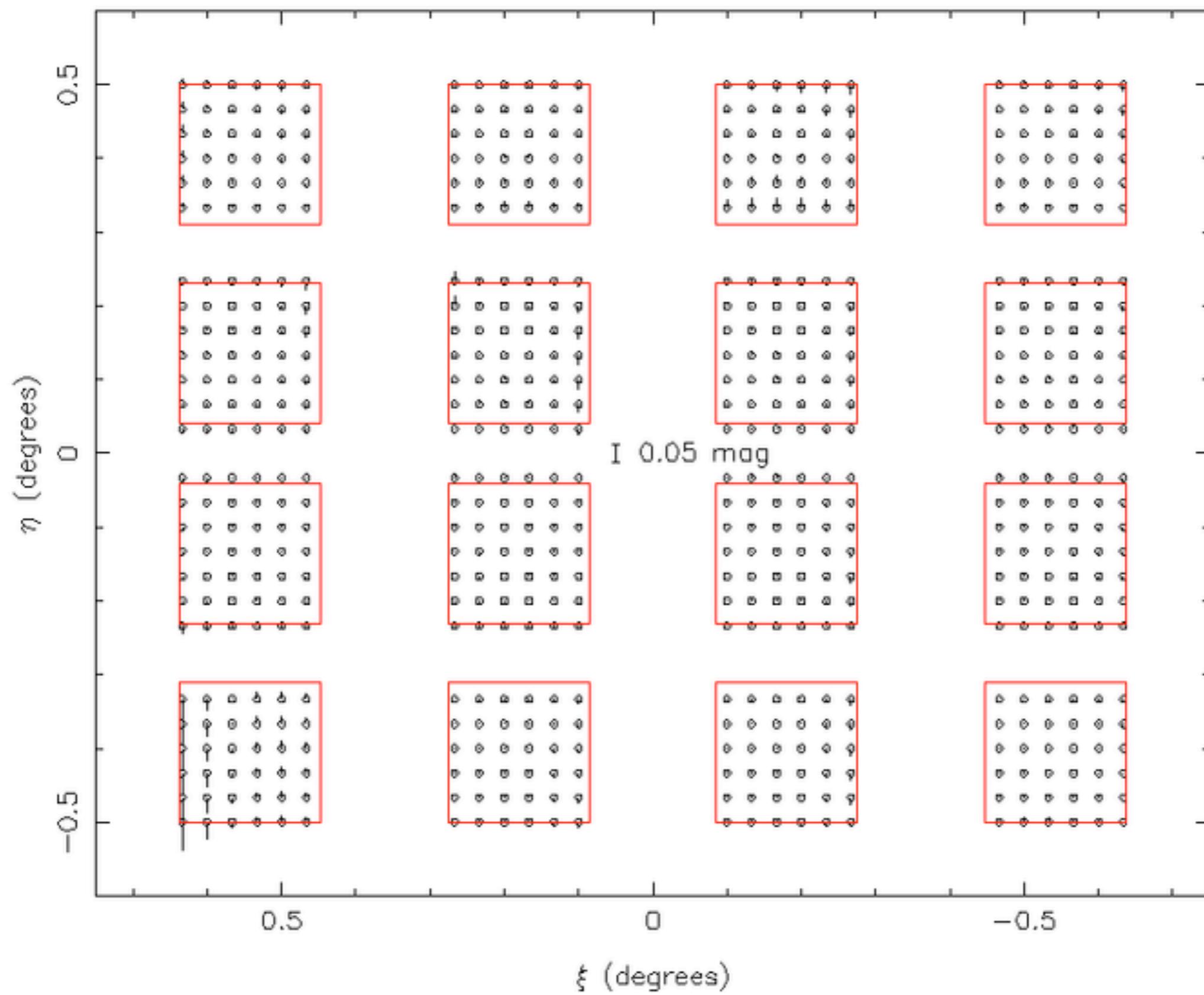
# Extinction Correction

- $ZP(Z)^* = ZP(Z)^* - 0.370 E(B-V)$
- $ZP(Y)^* = ZP(Y)^* - 0.140 E(B-V)$
- $ZP(J)^* = ZP(J)^* - 0.010 E(B-V)$
- $ZP(H)^* = ZP(H)^* - 0.015 E(B-V)$
- $ZP(Ks)^* = ZP(Ks)^* - 0.005 E(B-V)$

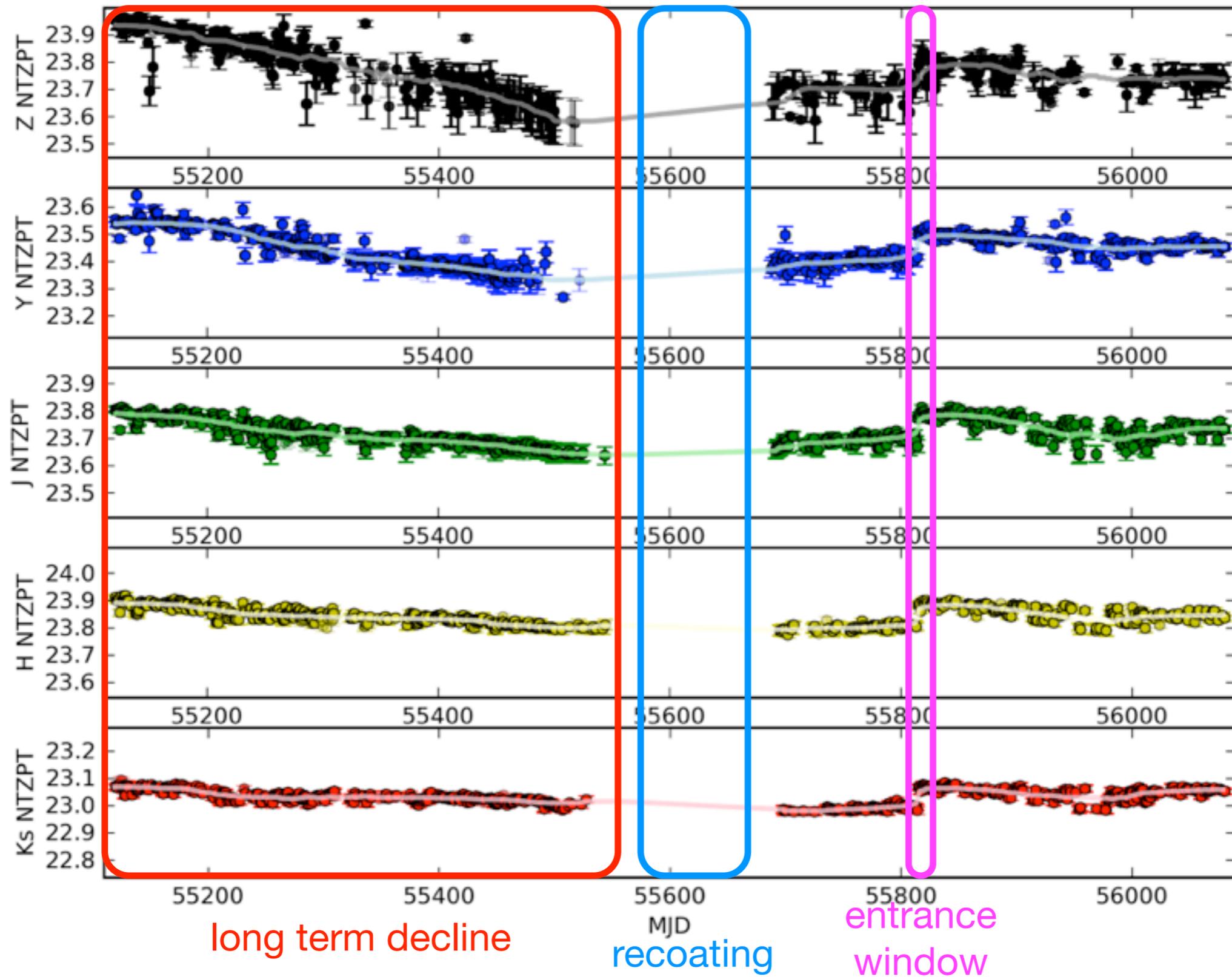
# method (ii)

- $ZP_{\text{det}}$  combined over all 16 detectors to give a single (per pointing) value:  $MAGZPT$ .
- stack the residuals ( $MAGZPT - ZP^*$ ) every month, corresponding to the change in master flatfield.
- the residuals are binned spatially (1.2x1.2 arcmin) and smoothed. two components are seen:
  - systematic detector offsets at the 1-2% level  
(catalogues/images are updated for each HDU)
  - additional spatial systematics at the 1% level  
(written to file and available from CASU)





# ZP vs Time



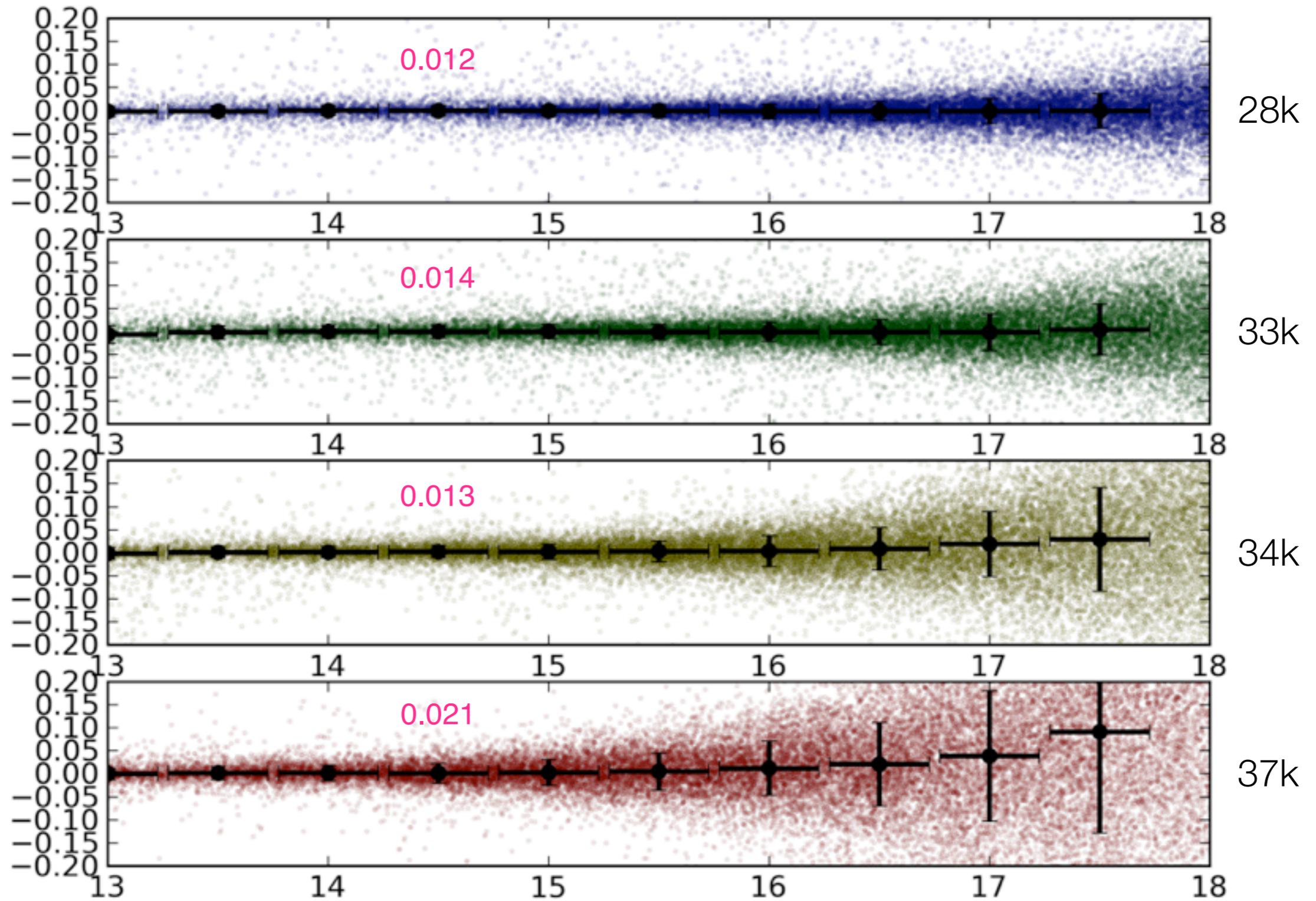
long term decline

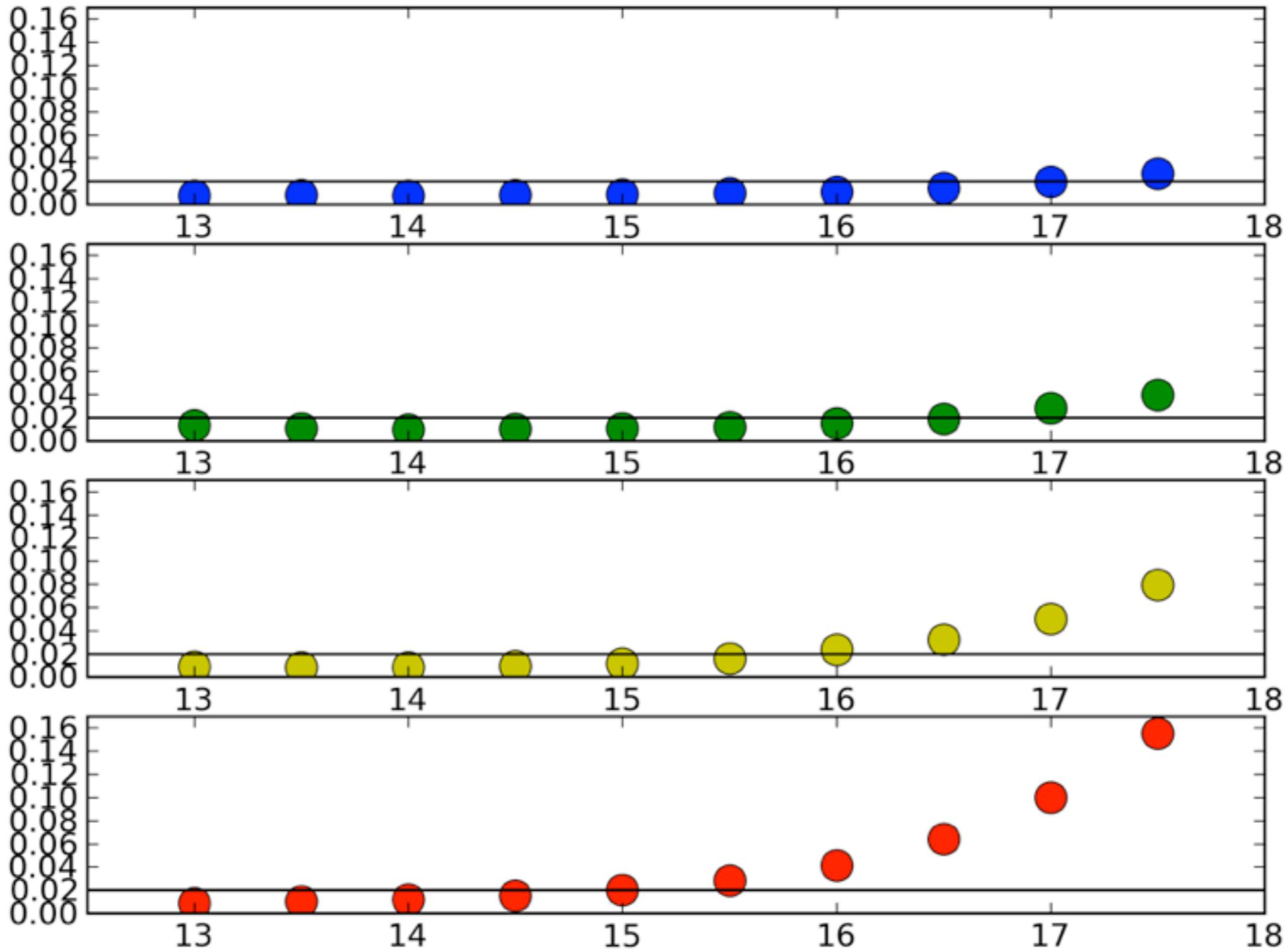
recoating

entrance window

# VHS Overlaps

**Stars VHS ATLAS overlaps  $13 < m_{12} < 18$ ,  $170 < ra < 175$ ,  $-15 < dec < -10$**

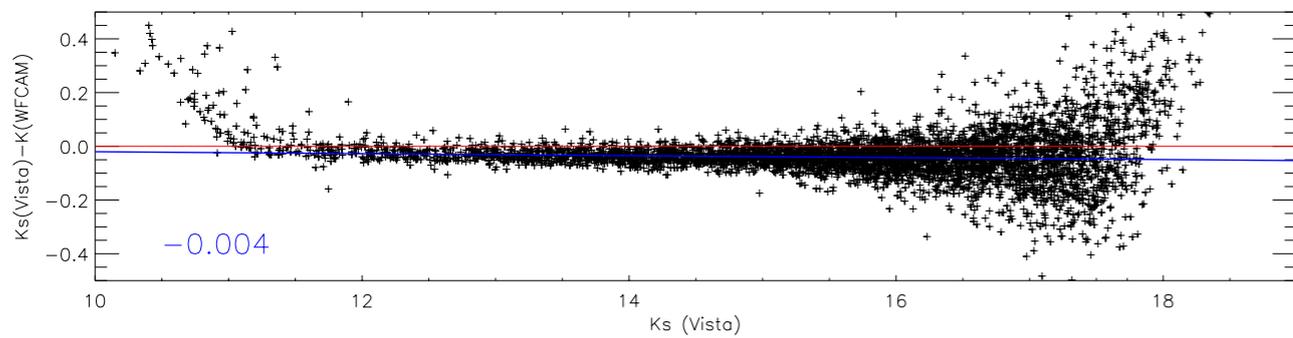
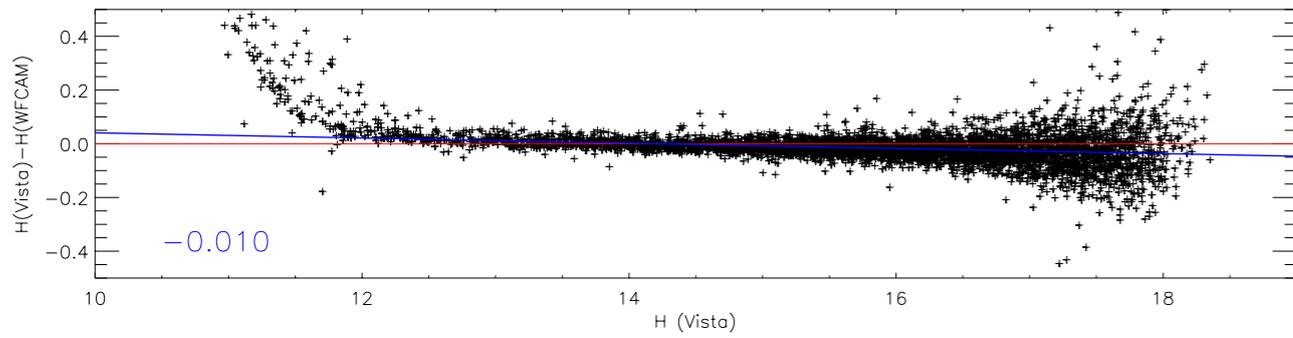
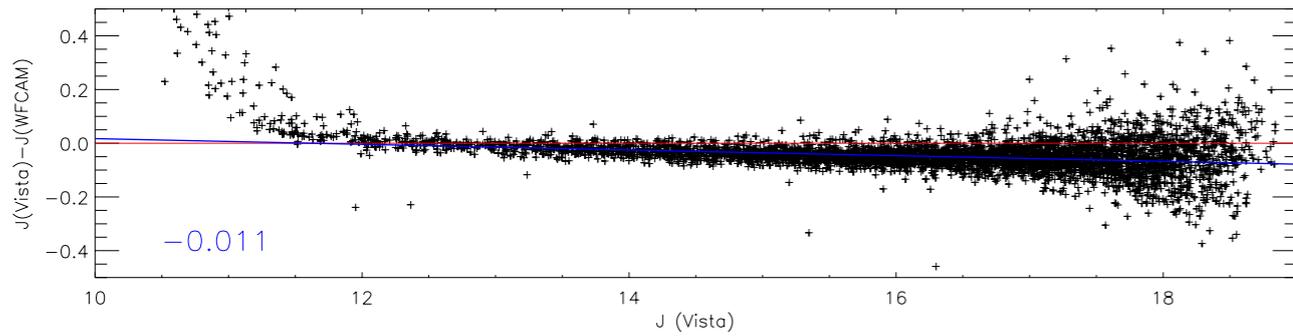
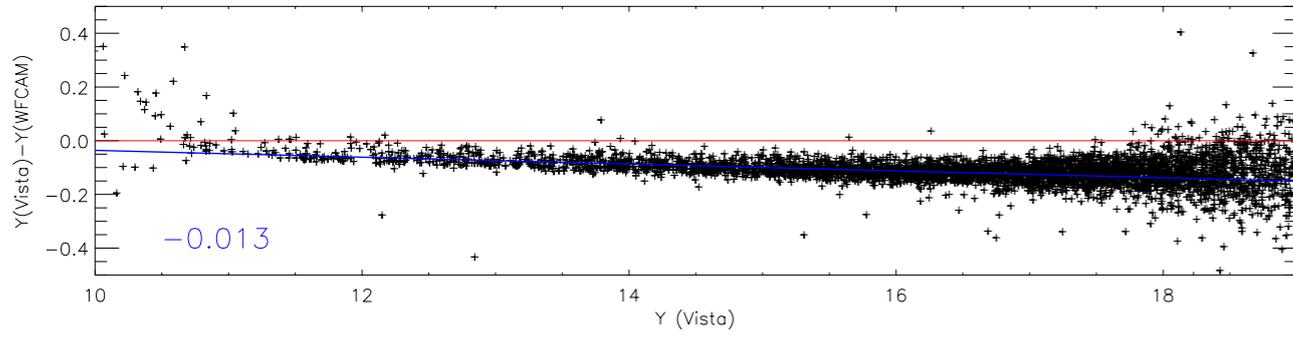
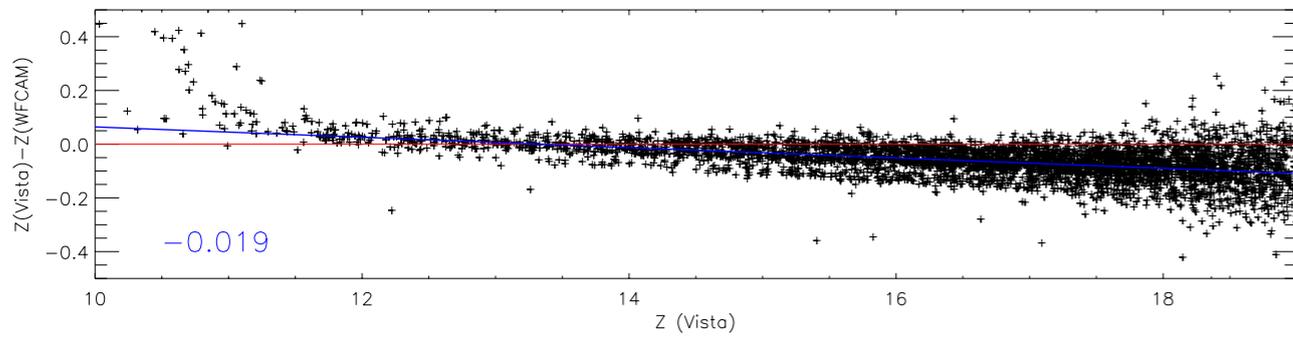


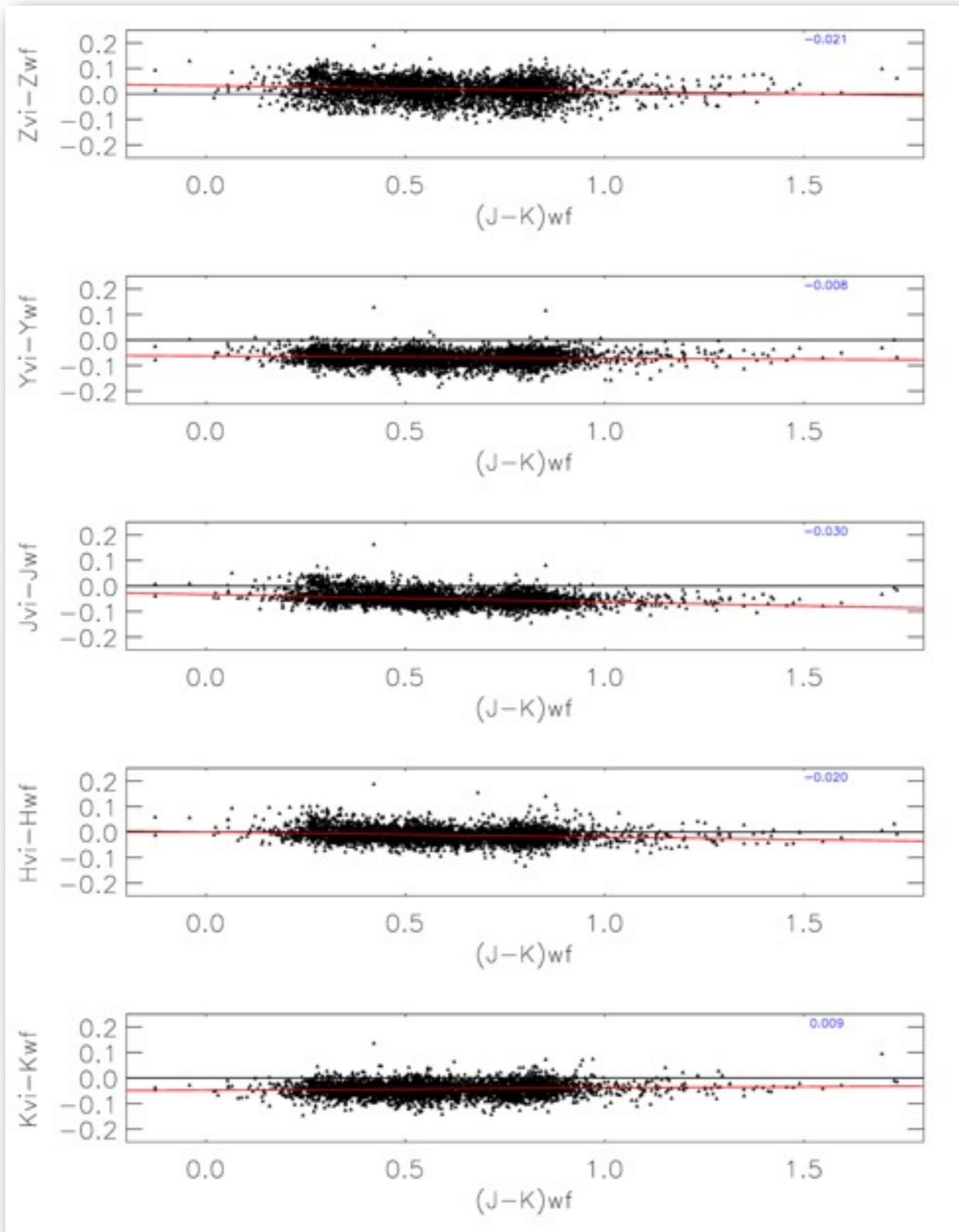


# VISTA vs WFCAM

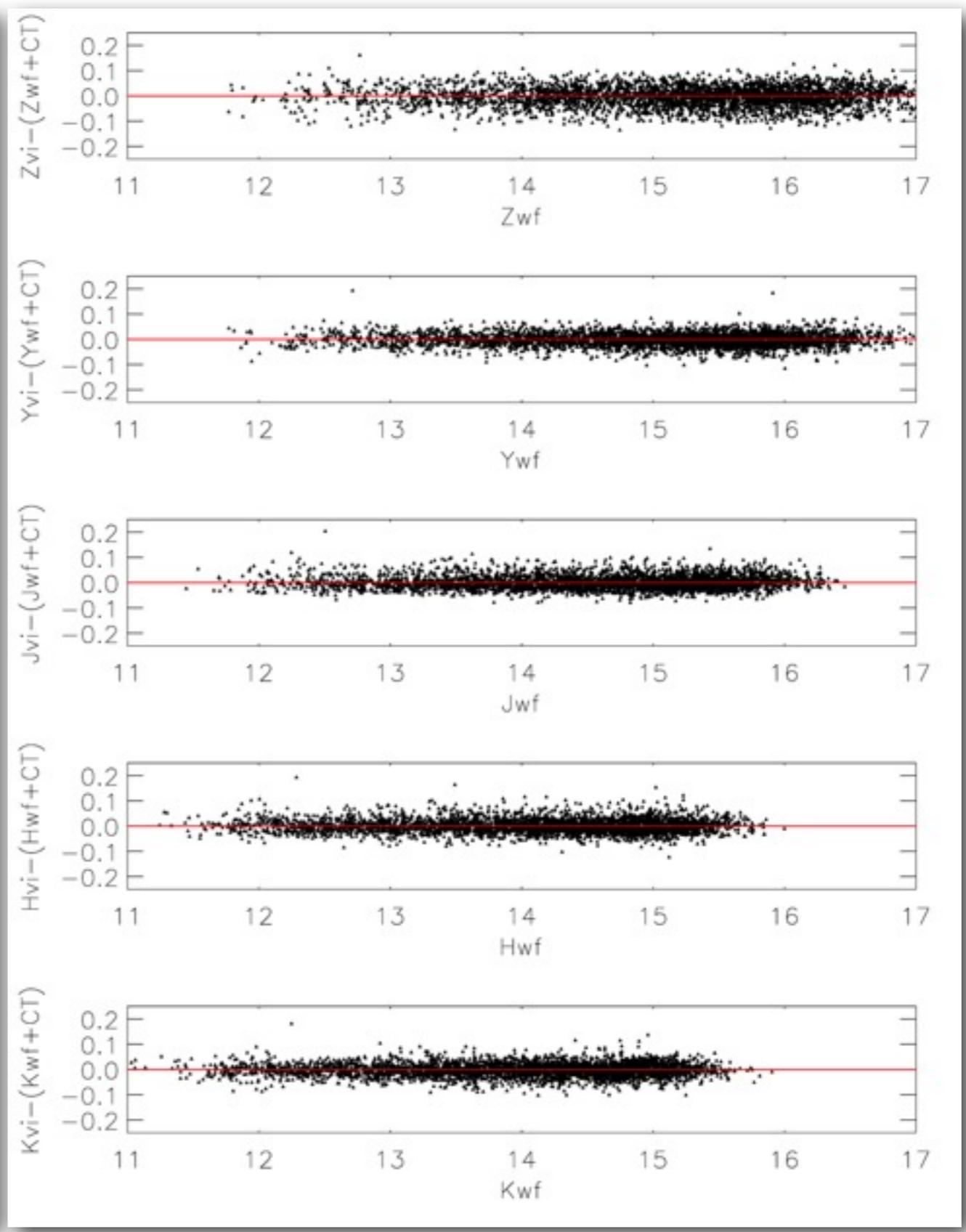
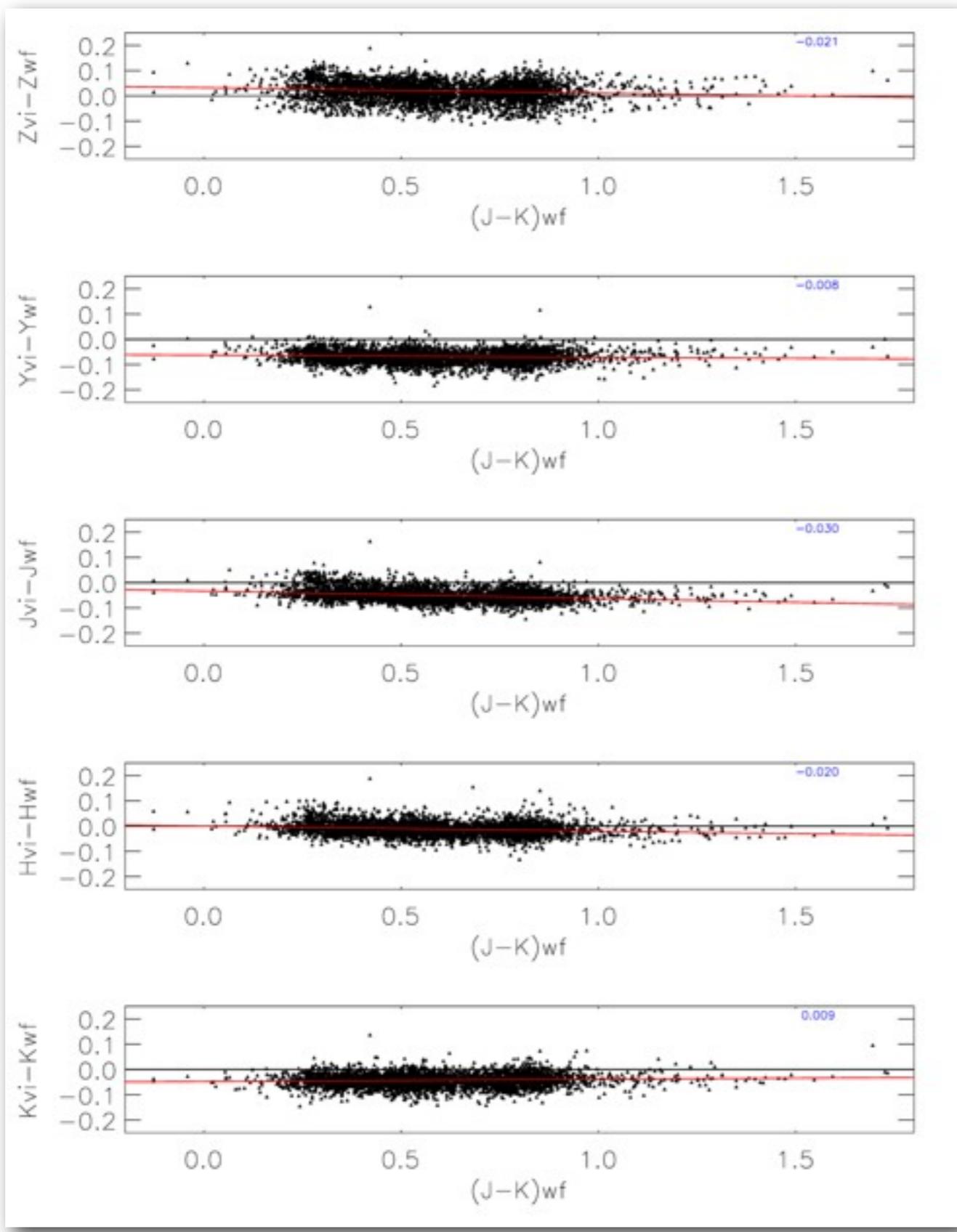
# VISTA/WFCAM calibration frames

- VISTA and WFCAM share some comparison/standard fields (should be - I chose them)
- 8 common equatorial fields with a minimum of 5 observations in all filters from both surveys

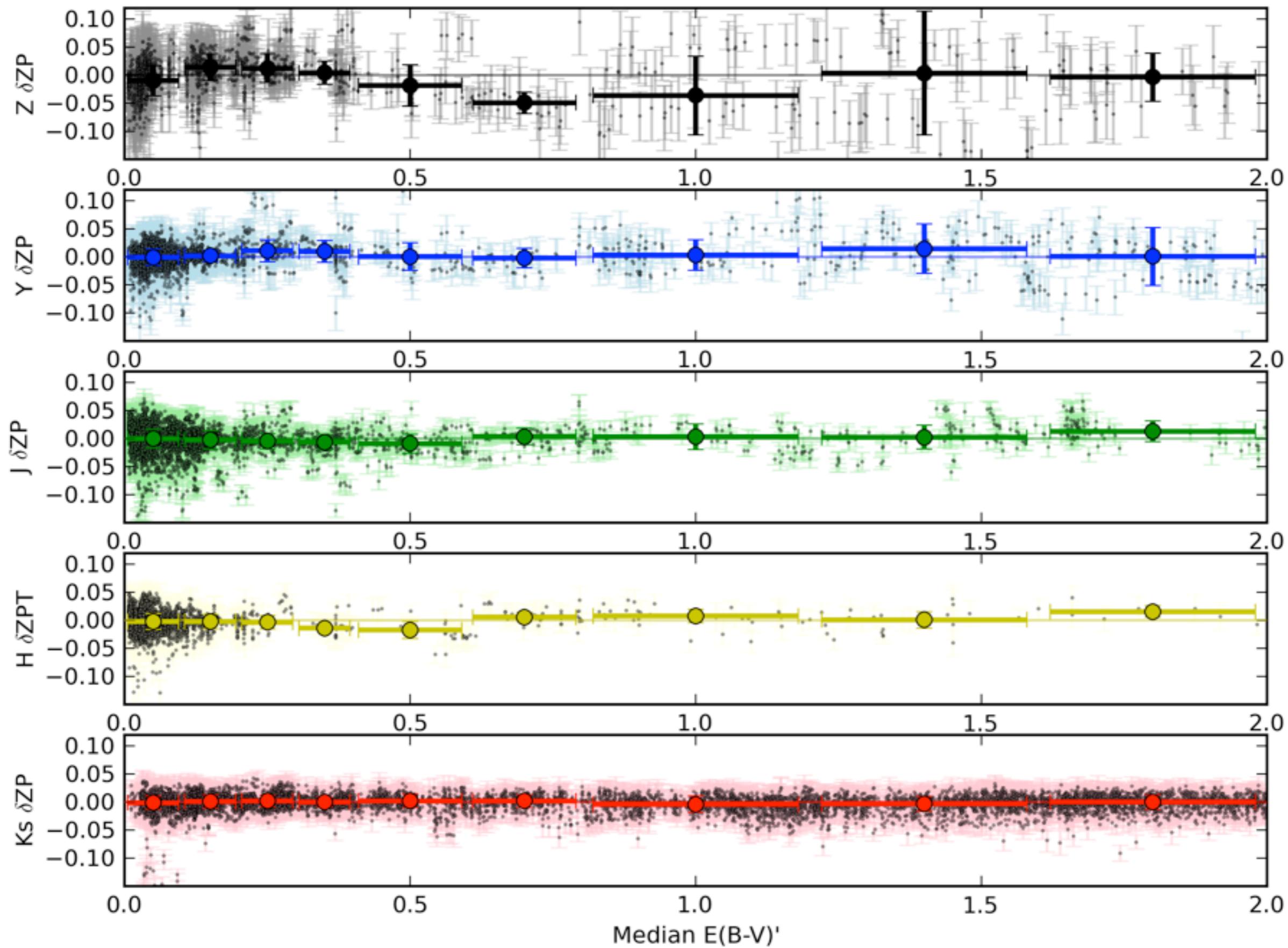


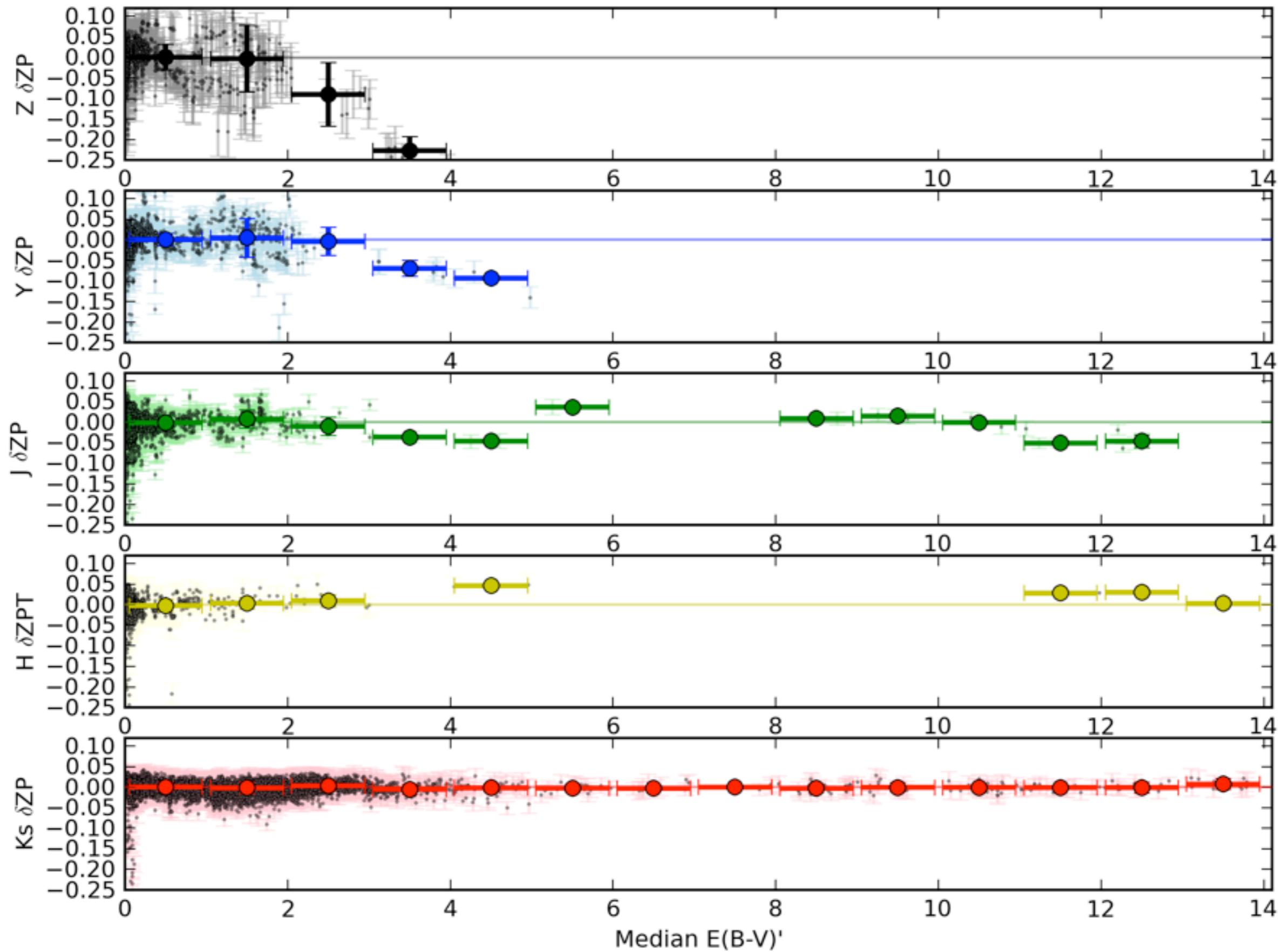


$$\begin{aligned}
 Z_{Vi} &= Z_{WF} - 0.021(J - K)_{WF} + 0.032 \\
 Y_{Vi} &= Y_{WF} - 0.008(J - K)_{WF} - 0.063 \\
 J_{Vi} &= J_{WF} - 0.030(J - K)_{WF} - 0.033 \\
 H_{Vi} &= H_{WF} - 0.020(J - K)_{WF} \\
 K_{S_{Vi}} &= K_{WF} - 0.009(J - K)_{WF} - 0.048
 \end{aligned}$$



# Interstellar Extinction





# VISTA throughput

The ratio of the scaled photons measured for a 0th magnitude star compared to the expected photons for Vega is then the throughput, and yields the following values (Z was not included in this initial analysis but has been factored in later). This does not yet include an analysis of any covariance in the detector noise properties, though earlier measurement on lab data suggested this was a much smaller effect than present in Rockwell Hawaii II devices. The WFCAM throughput is shown for comparison. The ETC columns uses all the latest data tables to directly compute the throughput ab-initio and compares favourably with the initial values deduced from the measured zeropoints.

Filter	VISTA	WFCAM	ETC (CASU v1.5)
Z	0.51	0.14	0.61
Y	0.45	0.17	0.52
J	0.53	0.21	0.55
H	0.66	0.28	0.67
Ks	0.63	0.27	0.61

## Comparison with WFCAM

Our simple analysis suggests that VISTA is a factor 2.5 (at YJHK) to 3.5 (at Z) times more efficient than WFCAM. VISTA has a smaller collecting area though, by around 20%, which means the differences in zeropoints between the instruments is more like a factor 1.6 to 3 (0.5 mags at K, 1.2 mags at Z).