photometric calibration from 2mass

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background

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The UKIRT wide field camera *ZYJHK* photometric system: calibration from 2MASS

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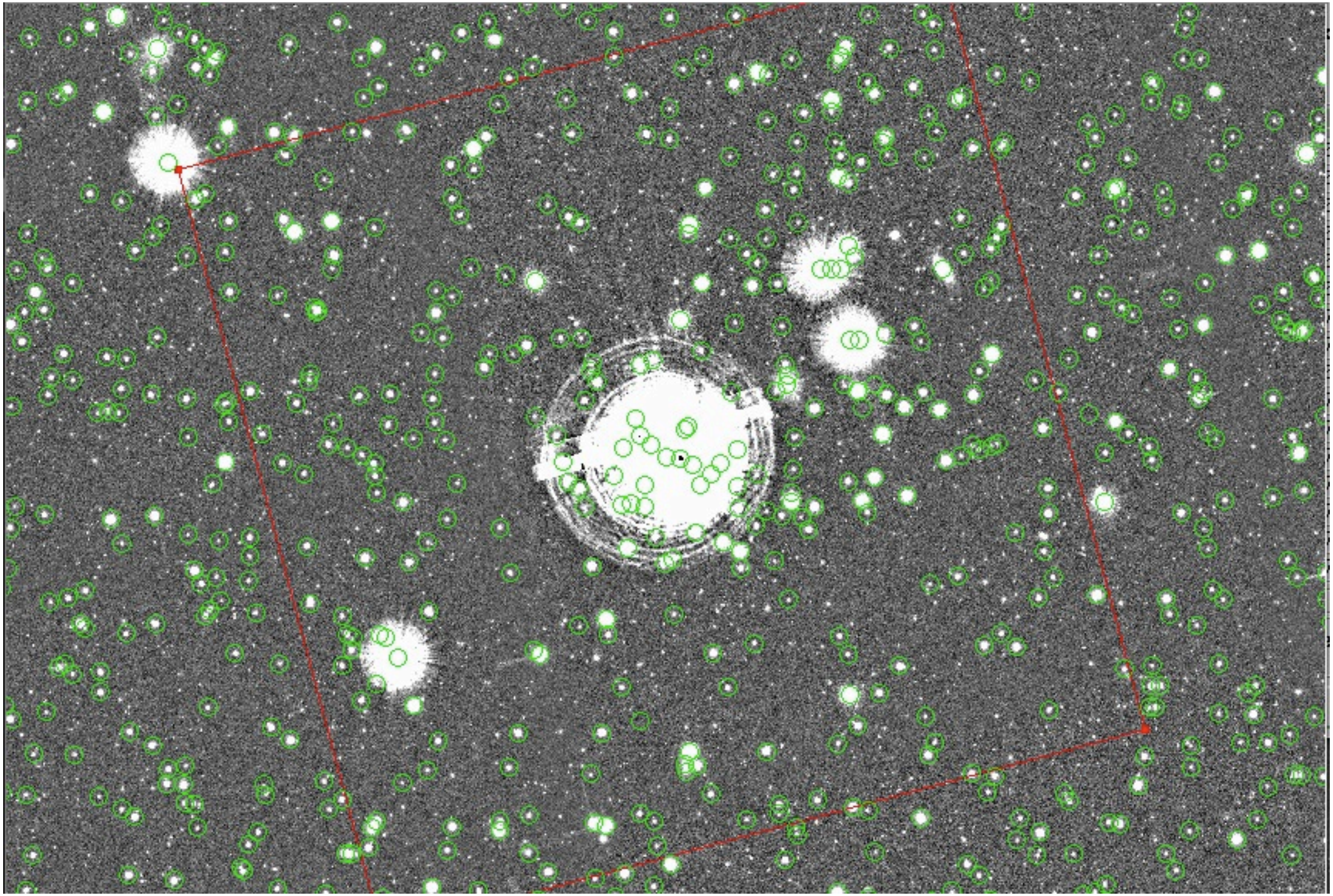
ABSTRACT

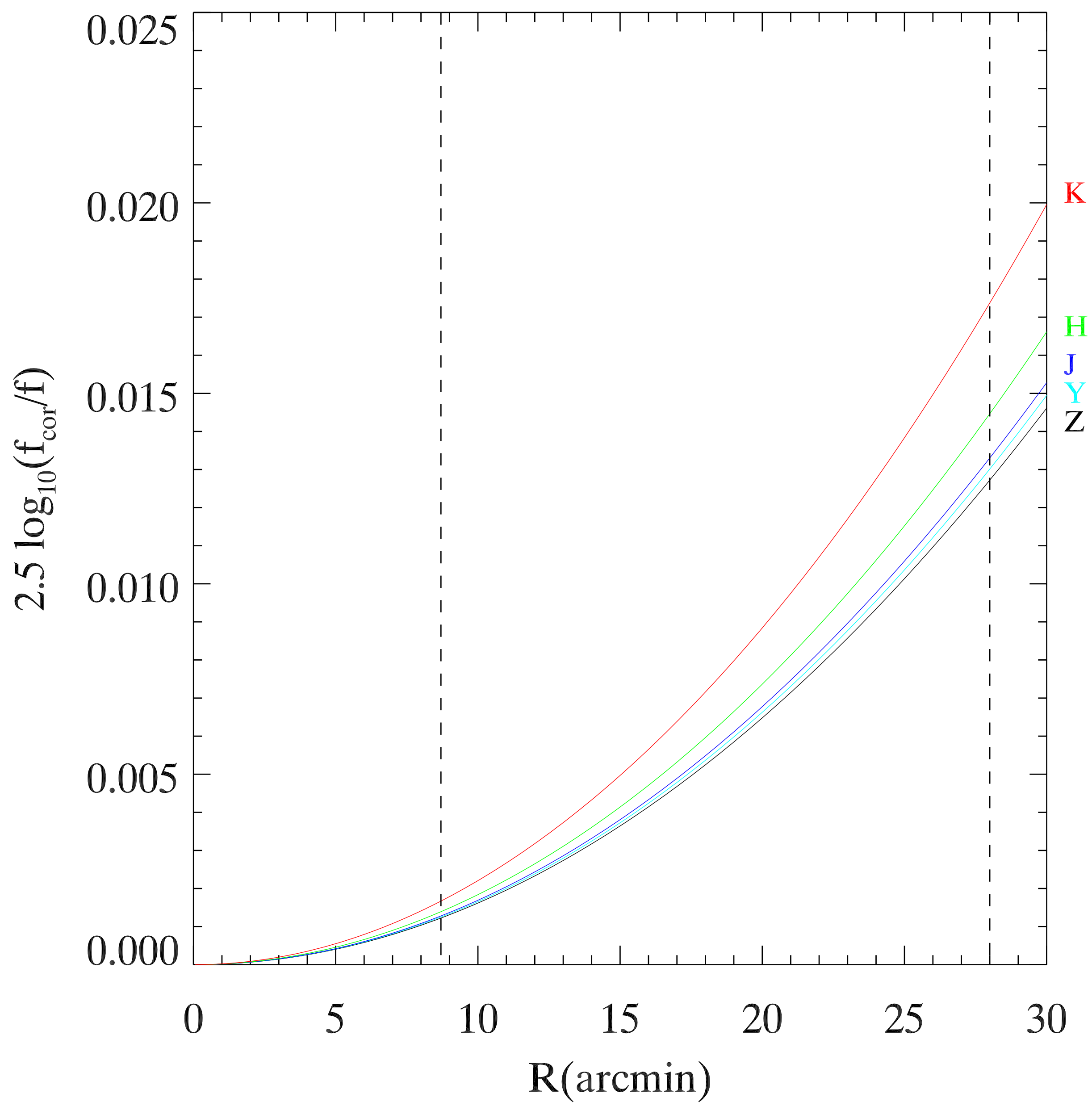
In this paper, we describe the photometric calibration of data taken with the near-infrared Wide Field Camera (WFCAM) on the United Kingdom Infrared Telescope (UKIRT). The broad-band *ZYJHK* data are directly calibrated from Two-Micron All-Sky Survey (2MASS) point sources which are abundant in every WFCAM pointing. We perform an analysis of spatial systematics in the photometric calibration, both inter- and intradetector show that these are present at up to the $\sim$5 per cent level in WFCAM. Although the causes of these systematics are not yet fully understood, a method for their removal is developed and tested. Following the application of the correction procedure, the photometric calibration of WFCAM is found to be accurate to $\simeq$1.5 per cent for the *JHK* bands and 2 per cent for the *ZY* bands, meeting the survey

sigma orionis: 2mass calibrators and a detector footprint



method

- flatfielding takes out first-order gain correction between the detectors (thus all 16 are on approximately the same calibration)
- correct instrumental magnitudes for radial distortion term (pixels are 1-2% bigger at the edge of the field)

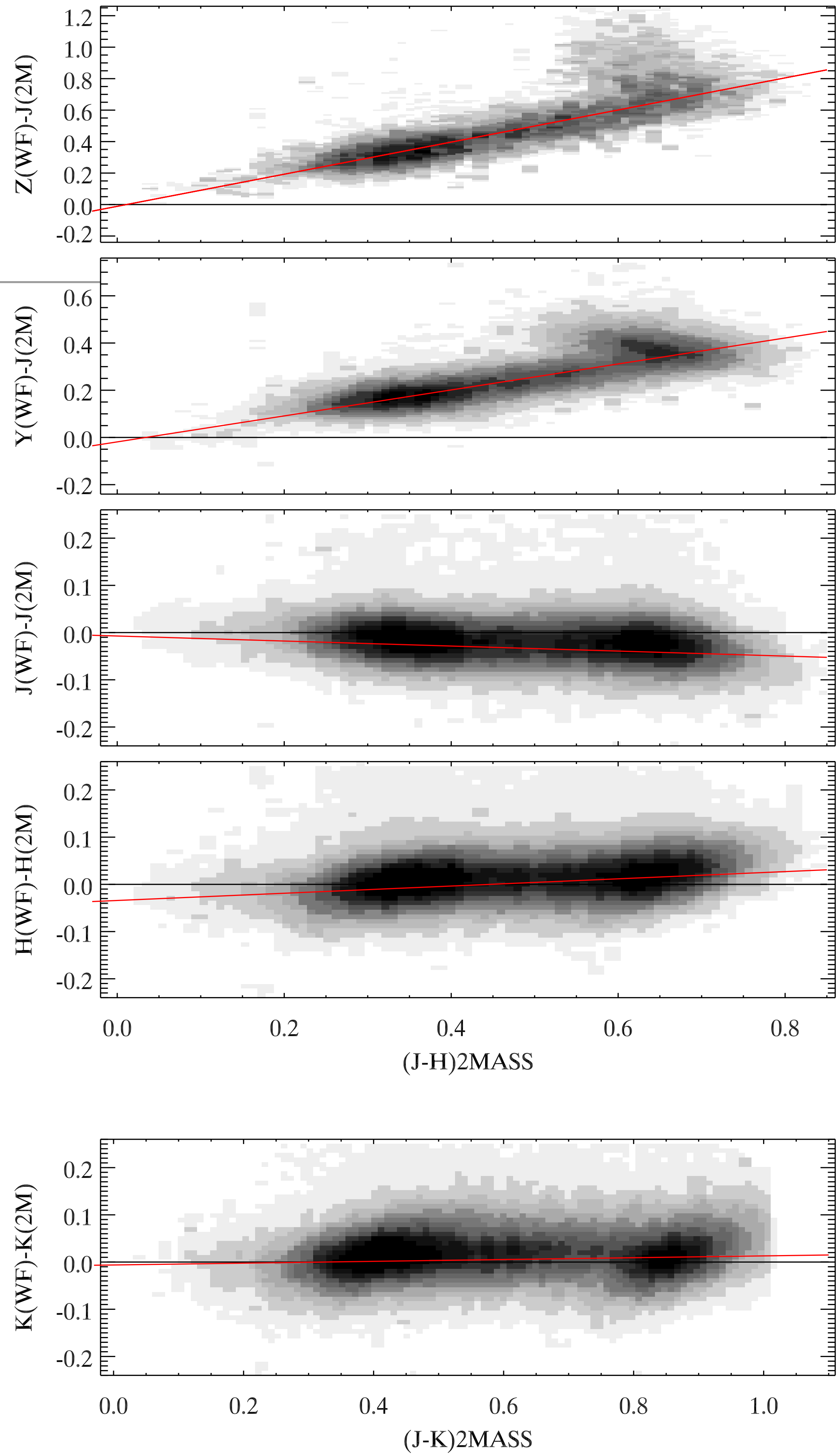


method

- flatfielding takes out first-order gain correction between the detectors (thus all 16 are on approximately the same calibration)
- correct instrumental magnitudes for radial distortion term (pixels are X% bigger at the edge of the field)
- per-detector ZPs determined from 2Mass stars

We assume that there exists a simple linear relation between the stellar 2MASS and WFCAM colours, e.g. $J_{\rm w} - J_2 \propto J_2 - H_2$. In a Vega-based photometric system, this relation should pass through (0,0), i.e. for an A0 star $Z = Y = J = H = K$, irrespective of the filter system in use. For each star in 2MASS observed with WFCAM, the pipeline derives a ZP (at airmass unity) from

$$ZP = m_2 + C(J_2 - H_2 \text{ or } J_2 - K_2) - m_i + k(\chi - 1), \qquad (3)$$



atmospheric extinction

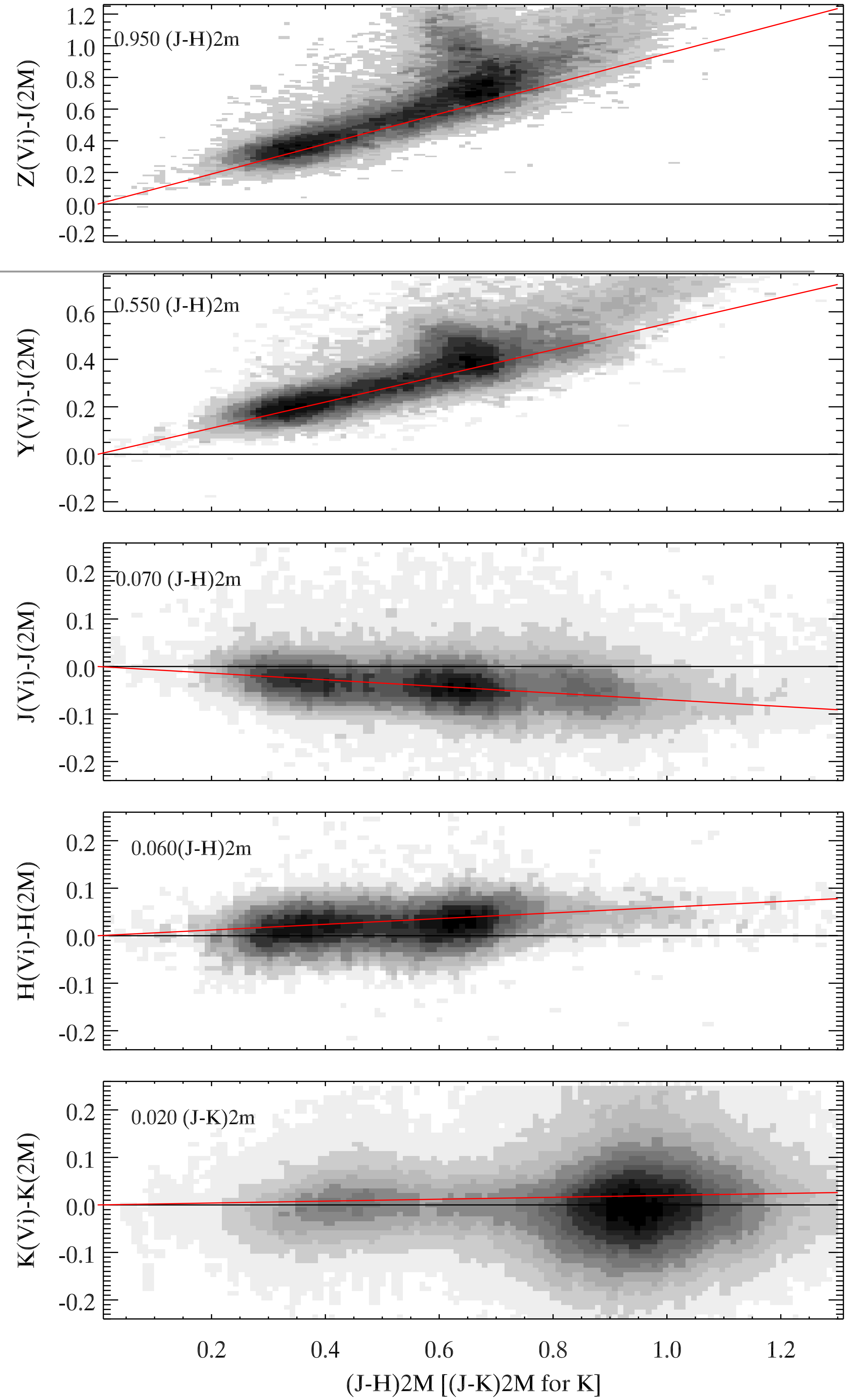
It should be noted that we do not derive any atmospheric extinction terms on a given night with WFCAM. Rather, the value of MAGZPT derived above incorporates an instantaneous measure of extinction at the observed airmass. The photometric calibration of a field therefore includes no error from this assumption. However, the derived zero-point for airmass unity will include a small error (because we assume the extinction is 0.05 mag per airmass for all filters). Leggett et al. (2006) find the extinction at Mauna Kea to be $k_J = 0.047$, $k_H = 0.029$, $k_K = 0.052$ with standard deviations between 0.2 and 0.3. For a typical WFCAM frame, observed at an airmass $\approx$1.3, an extinction which differs from our assumed value by 0.03 mag airmass^{-1} will lead to a 0.01 mag error in the value of MAGZPT. The value of MAGZPT over time can be used to investigate the long-term sensitivity of WFCAM due to, for example, the accumulation of dust on the optical surfaces, and seasonal variations in extinction.

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:

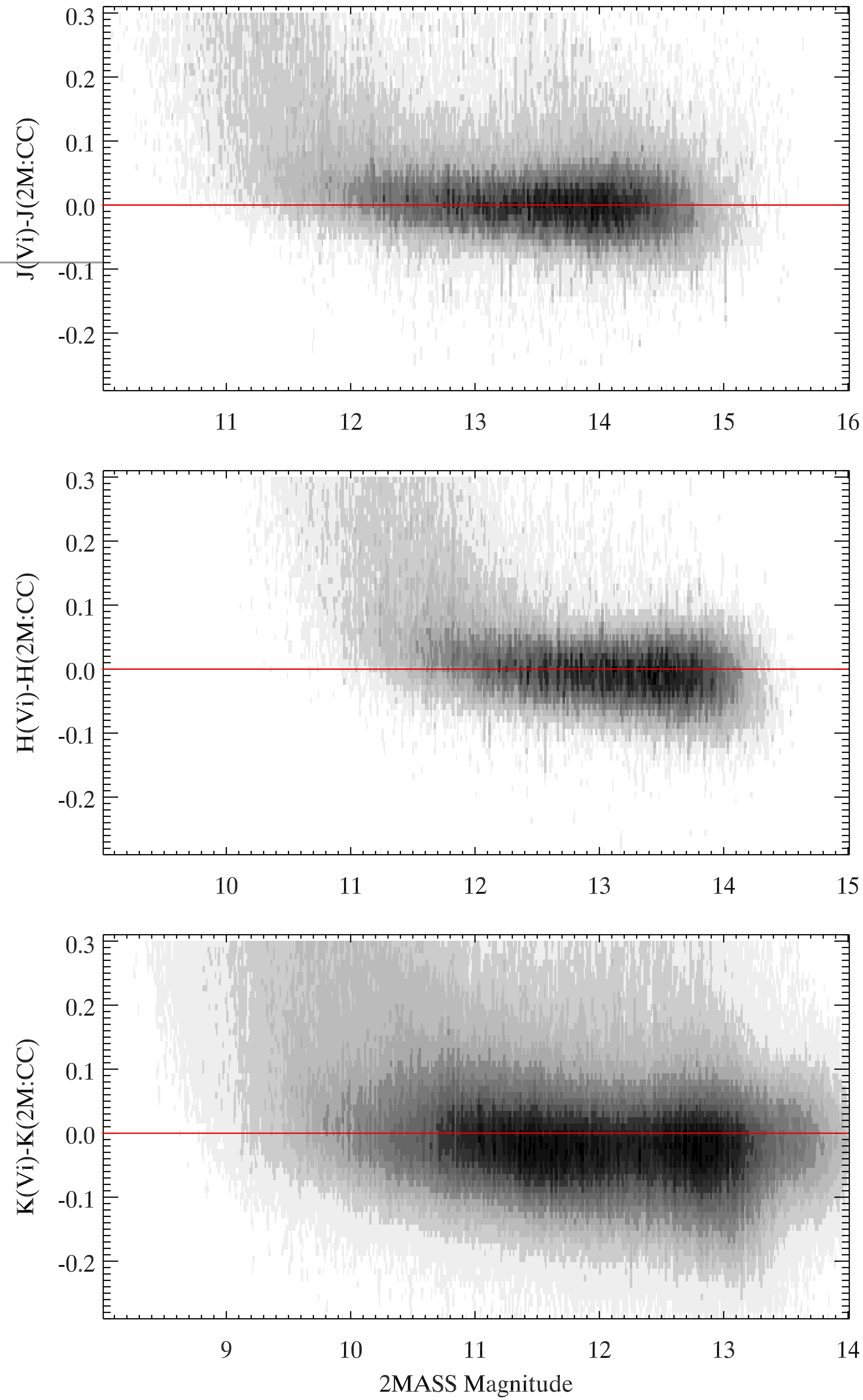
$$
\begin{aligned}
Z_V - J_2 &: \ \ 0.950(J-H)_2 \\
Y_V - J_2 &: \ \ 0.550(J-H)_2 \\
J_V - J_2 &: -0.070(J-H)_2 \\
H_V - H_2 &: \ \ 0.060(J-J)_2 \\
K_V - K_2 &: \ \ 0.020(J-K)_2
\end{aligned}
$$

- for each detector we measure a per-star ZP after correcting the 2Mass phoomotery onto the VISTA system



residual non-linearities

- are demonstrably small after removing colour terms,
- but need quanitfying (per detector) : ideally without recourse to 2MASS (which may show residual non-linearities wrt WFCAM)
- keyword per extension already handles saturation



reddening in WFCAM

- colour restriction imposed on 2MASS calibration stars: 0<J-K<1
- regions with high extinction typically contain modified spectra of unusual (e.g. giant) populations
- correction applied as a function of E(B-V)' [Bonifacio et al. 2000]

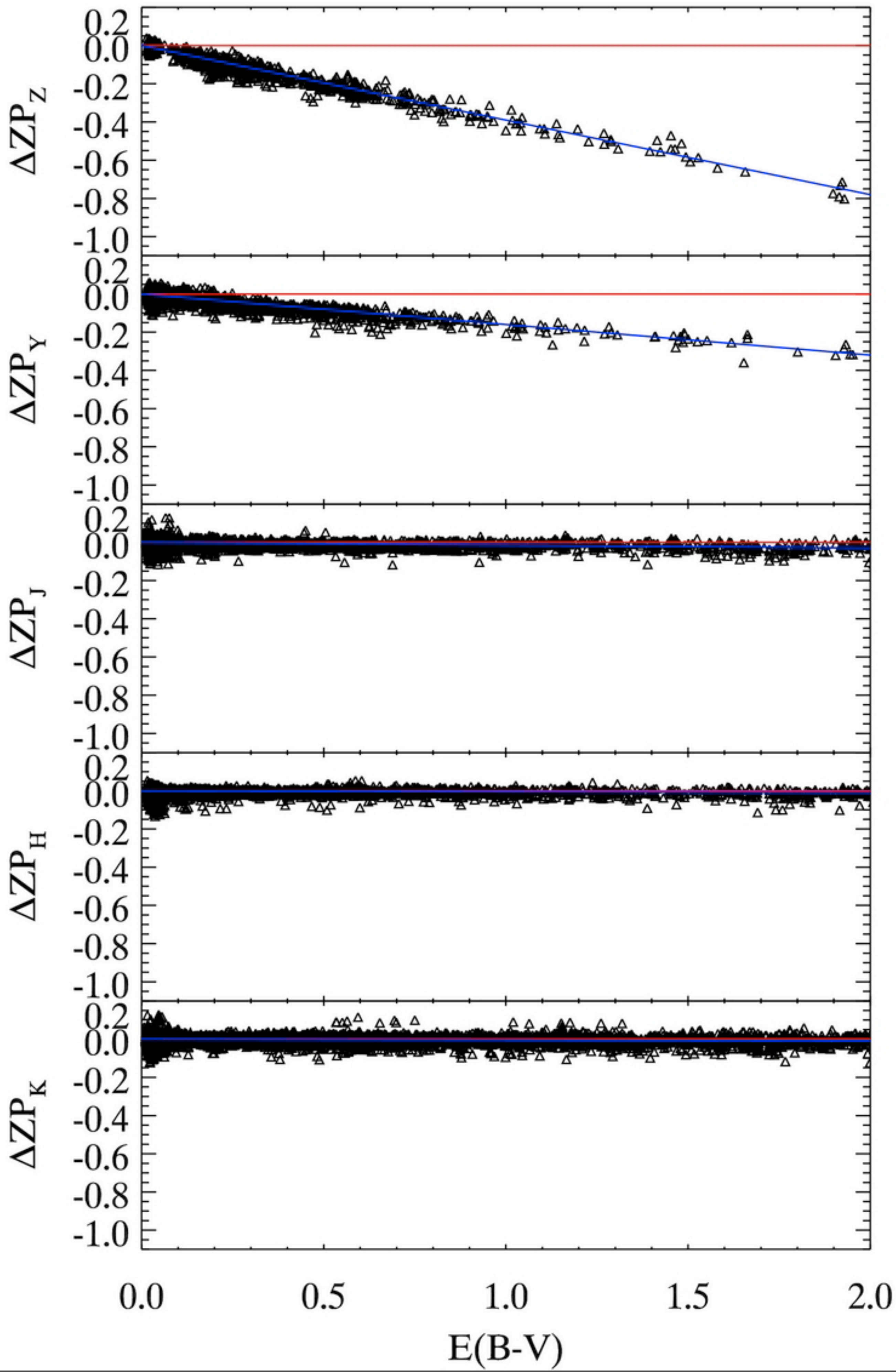
$$ZP'(Z) = ZP(Z) - 0.390E(B-V)', \tag{9}$$

$$ZP'(Y) = ZP(Y) - 0.160E(B-V)', \tag{10}$$

$$ZP'(J) = ZP(J) - 0.015E(B-V)', \tag{11}$$

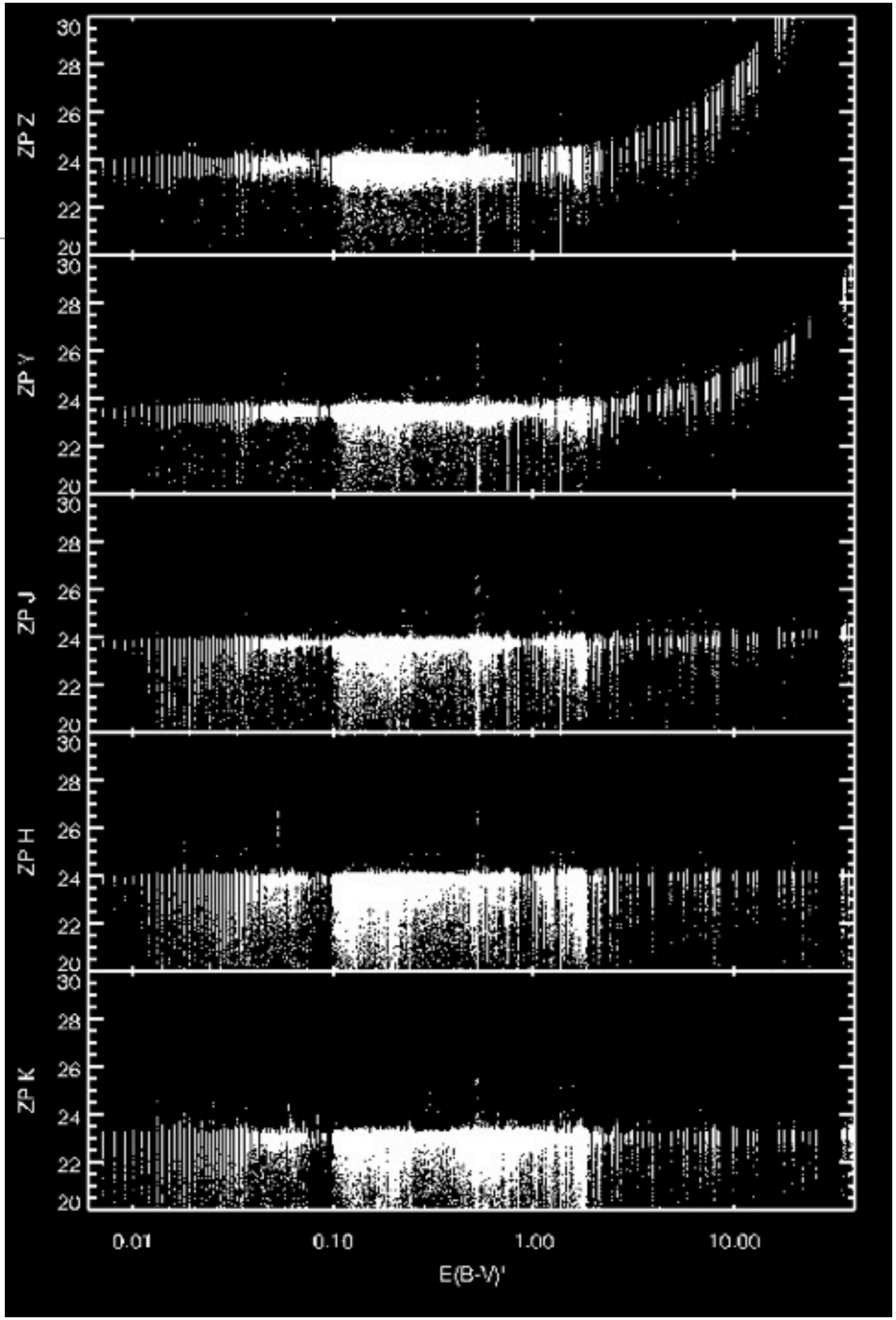
$$ZP'(H) = ZP(H) - 0.005E(B-V)', \tag{12}$$

$$ZP'(K) = ZP(K) - 0.005E(B-V)'. \tag{13}$$



reddening in VISTA

- correction based on WFCAM only explored to E(B-V)=2.0
- curvature in Z, Y (J) at high E(B-V) indicates that we are overcorrecting beyond E(B-V)>2.0
- `snow' largely because data includes all commissioning data, non-photometric nights, lost guiding images.
- Schlegel resolution is rather coarse ~5 arcminutes, and has no distance resolution.



so what happens when stellar population varies ?

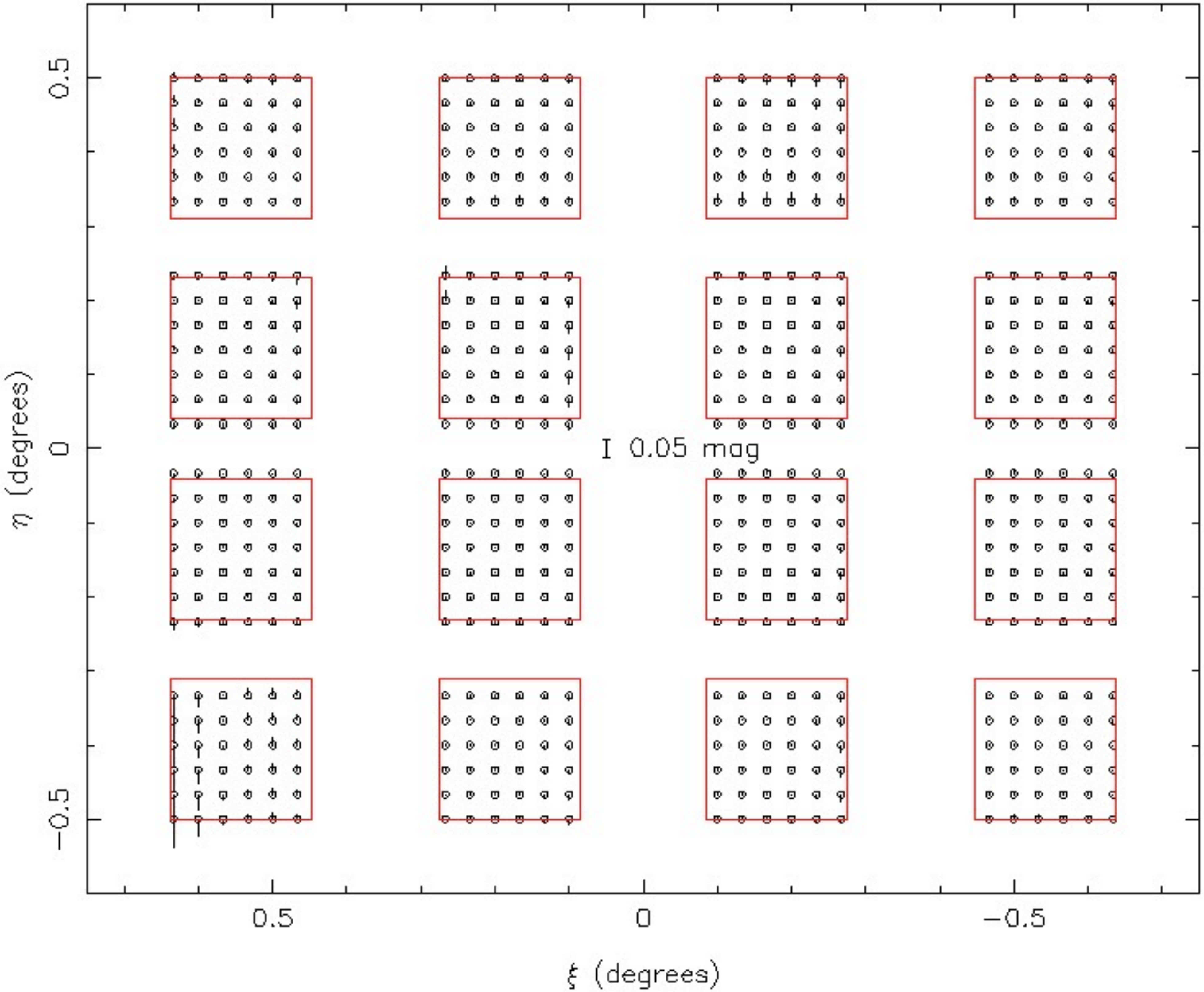
- photometric calibration in JHKs is robust against reddening/population
- ZY will have issues. Options are:
  - Accept the best-efforts E(B-V) corrected ZPs
  - Use the nightly zeropoints derived for frames with negligible E(B-V) or more ‘normal’ stellar populations
  - Use calibration field observations (how often will these be done, what about ZY standards?)

residual per-detector offsets

- flatfielding puts all 16 detectors on approximately the same photometric system
- flatfields are updated approximately monthly
- small offsets may arise from QE differences between the detectors: the twilight sky used in flatfielding is significantly bluer than the dark sky
- stacking of 2mass calibrators (per star zeropoints) used to measure these offsets: less than 2% for WFCAM and updated ~monthly

residual spatial systematics

- after removing per-detector offsets we see a residual spatial systematic in VISTA (J-band)
- it's generally less than 1%
- except for detector 16



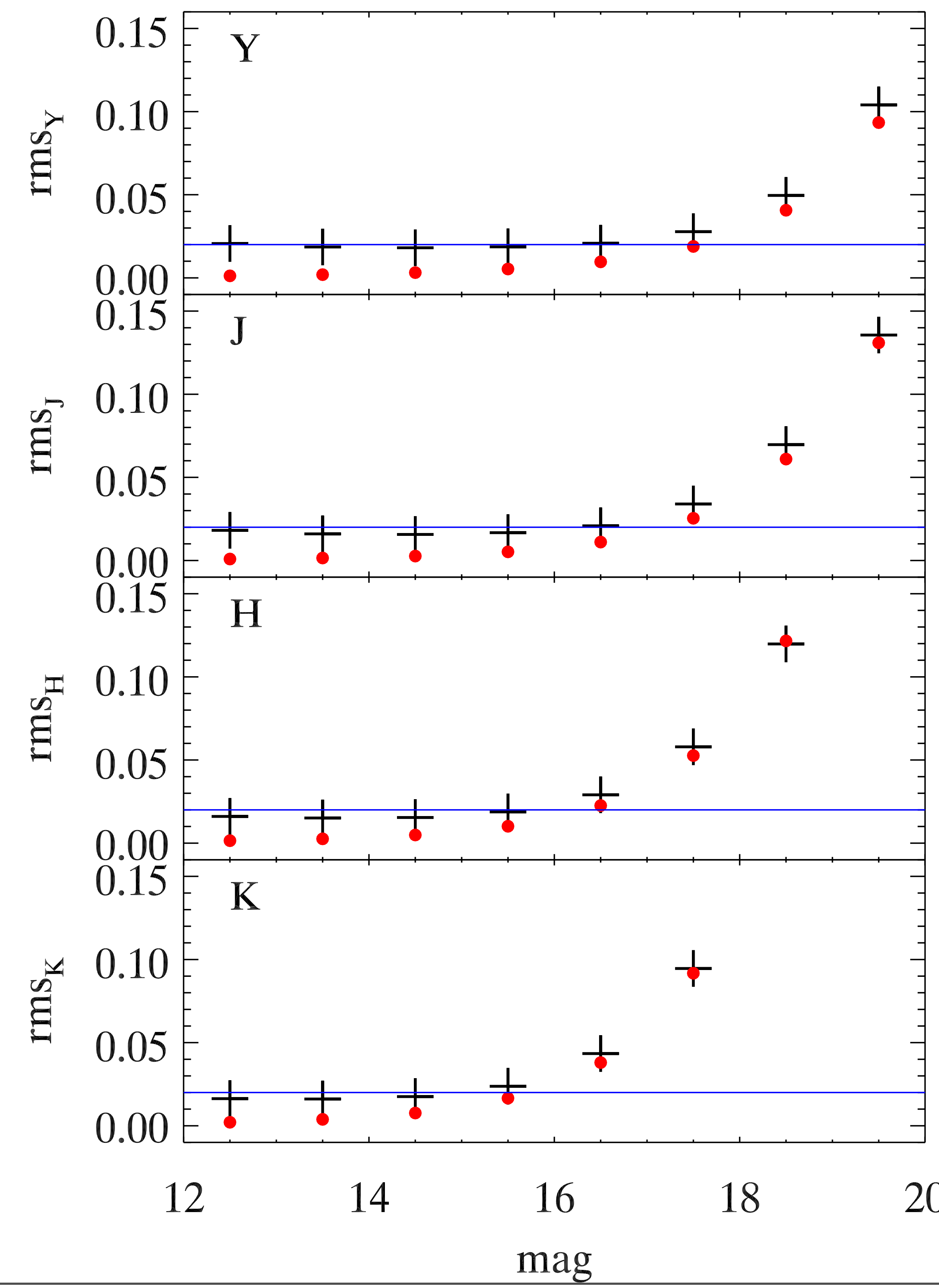
WFCAM overlaps

- we can use repeat observations of sources to measure the photometric accuracy and homogeneity

- for the UKIDSS LAS, there is overlap within and between tiles.

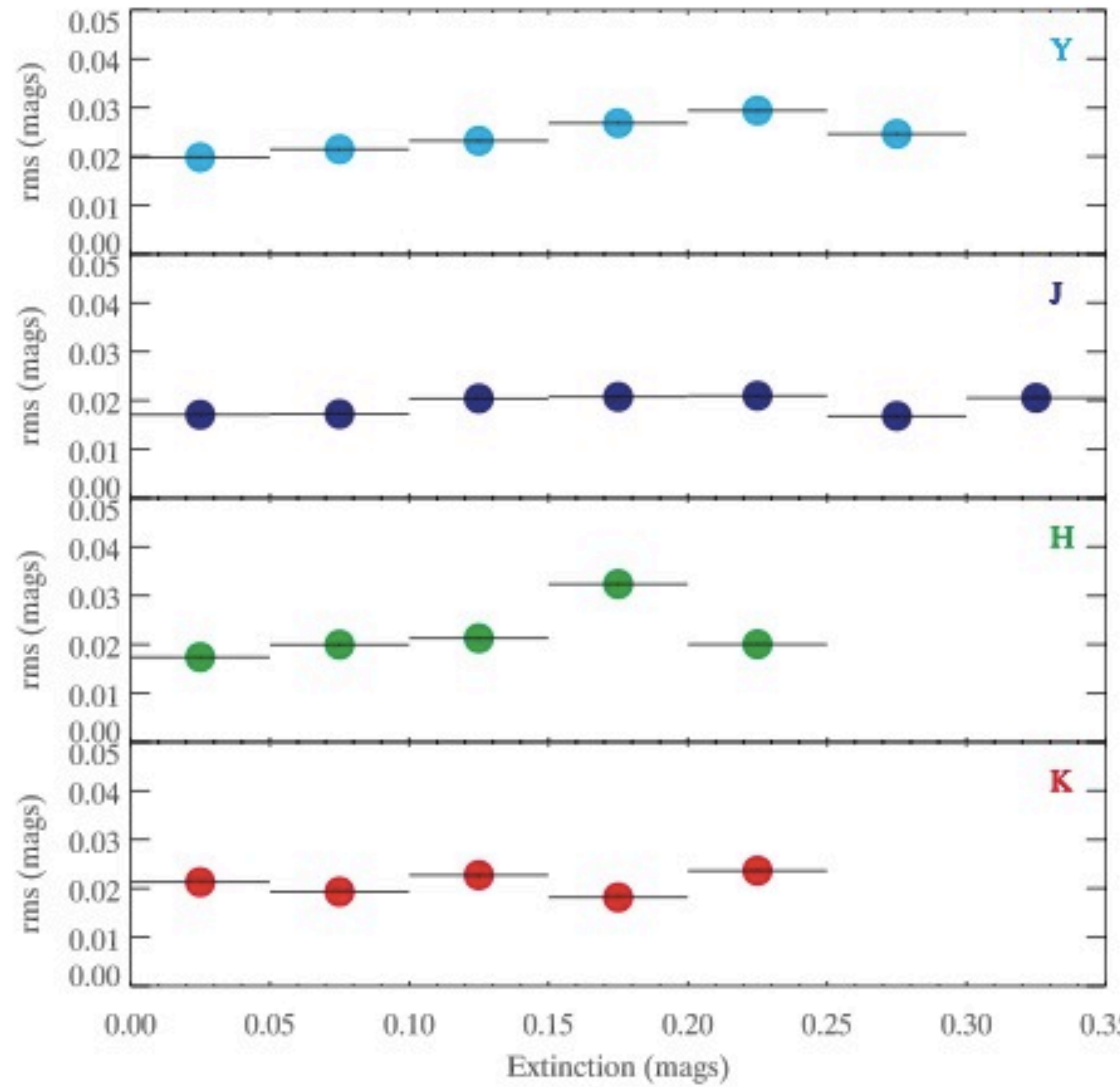
Table 2. rms at mag = 13.5 for the WFCAM filters derived from repeat observations of sources in the LAS and standard star fields.

	LAS				STD
Filter	rms_{DR2}	rms_{DR3}	$rms_{spatial}$	rms_{cloudy}	rms_{STD}
Z_W	–	–	–	–	0.015
Y_W	0.023	0.021	0.019	0.021	0.013
J_W	0.021	0.018	0.016	0.022	0.012
H_W	0.022	0.017	0.015	0.021	0.011
K_W	0.023	0.020	0.016	0.020	0.011

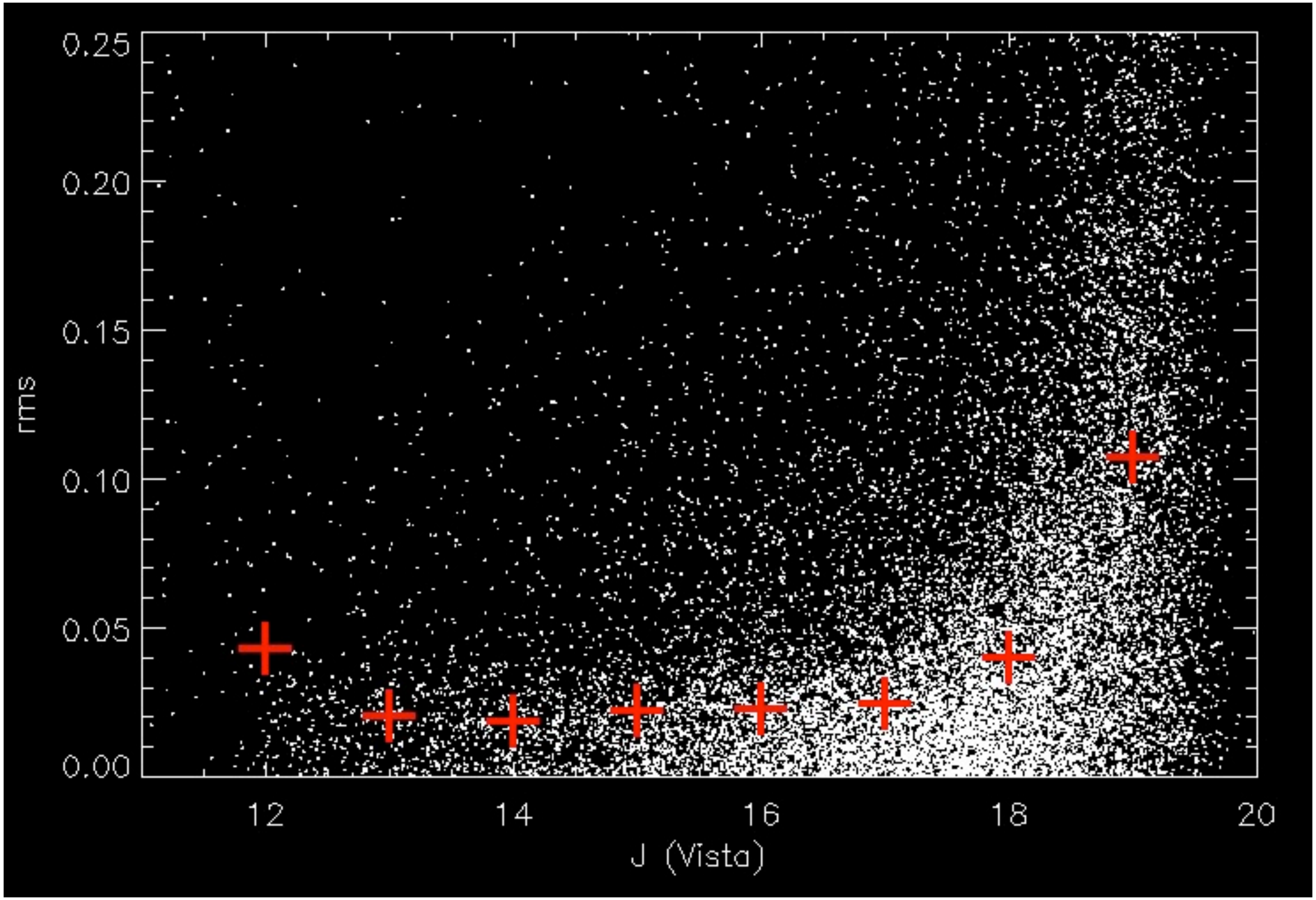


WFCAM: calibration in poorer conditions

Even observations taken through thin cloud (where transmission is >80 per cent) can be calibrated to ~2 per cent using 2MASS calibrators.

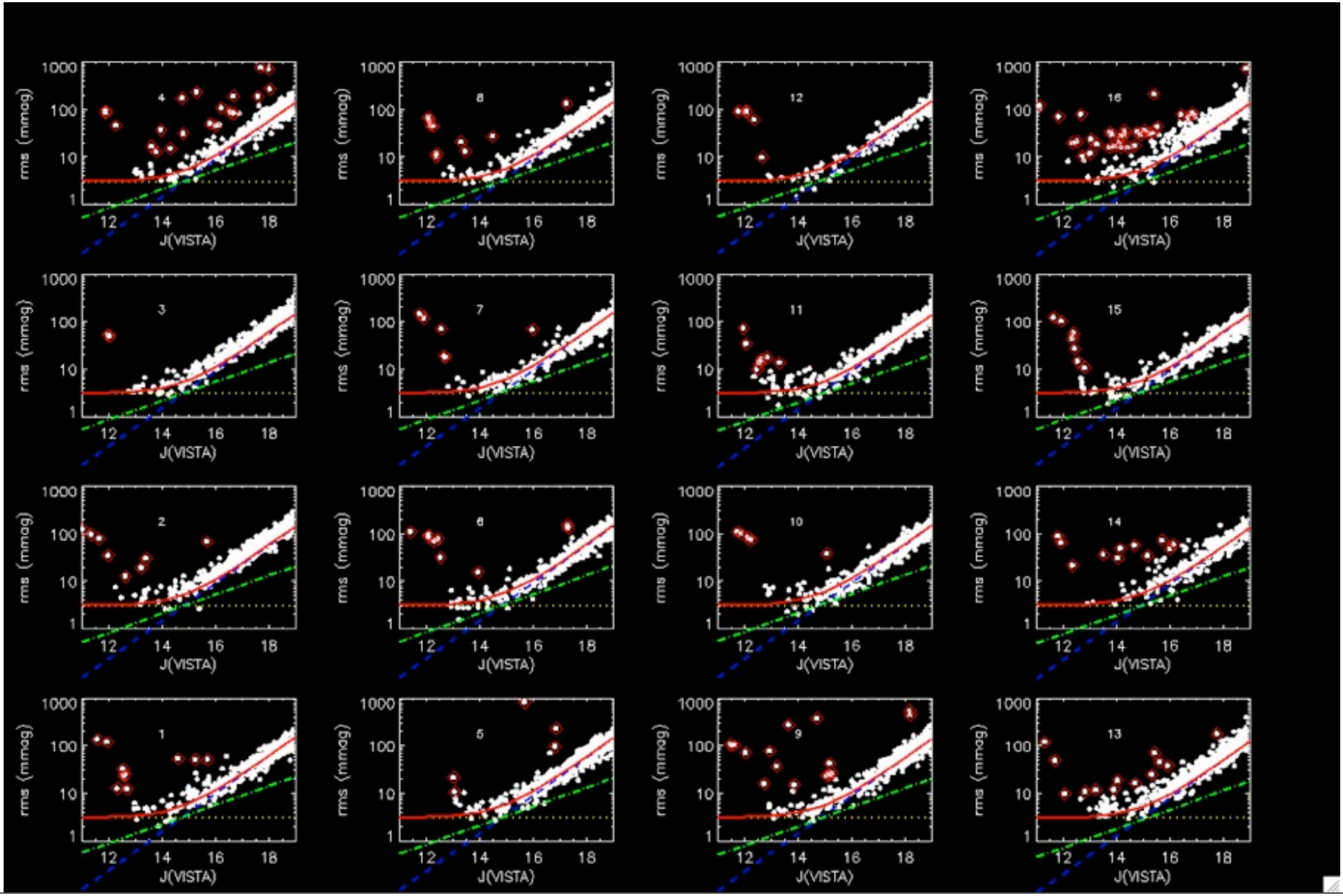


VISTA
overlapping tiles (Jband) [10 pairs of tiles in Orion]



nb: the tile catalogues are not (yet) corrected for the radial distortion term

rms diagram for Orion dataset



VISTA throughput

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

Filter	VISTA	WFCAM	ETC (CASU v1.4)
Z	0.51	0.14	0.67
Y	0.45	0.17	0.57
J	0.53	0.21	0.60
H	0.66	0.28	0.72
Ks	0.63	0.27	0.70

Filter	ZP (ADU)	ZP (e-)	Colour equation
Z	23.95	25.51	+0.950*(J-H)
Y	23.50	25.06	+0.550*(J-H)
J	23.79	25.35	- 0.070*(J-H)
H	23.89	25.45	+0.060*(J-H)
Ks	23.06	24.62	+0.020*(J-Ks)
NB118	20.92	22.48	+0.100*(J-H)

to do

- calibration of the colour-colour diagrams: are we on a Vega system?
- explore reddening and update relations for VISTA (and WFCAM)
- compare VISTA vs WFCAM photometry directly (some standard fields overlap)
- derive transformations between other systems
- measure overlaps between pawprints
- calibration of tile catalogues
- comparisons with synthetic photometry
- narrow band filters: illumination correction