The ESO FORS Absolute Photometry Project (FAP)

Wolfram Freudling

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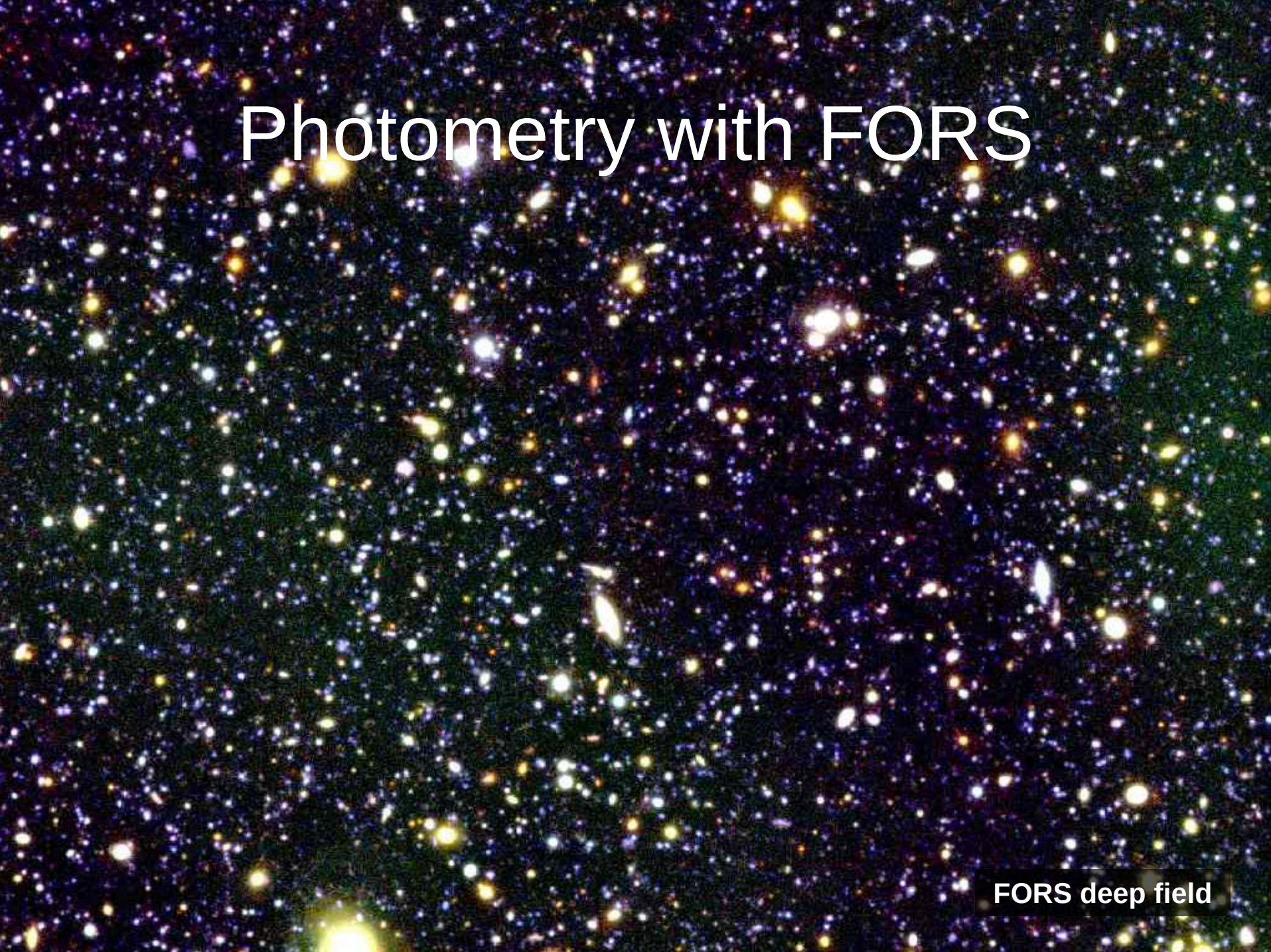
FORS

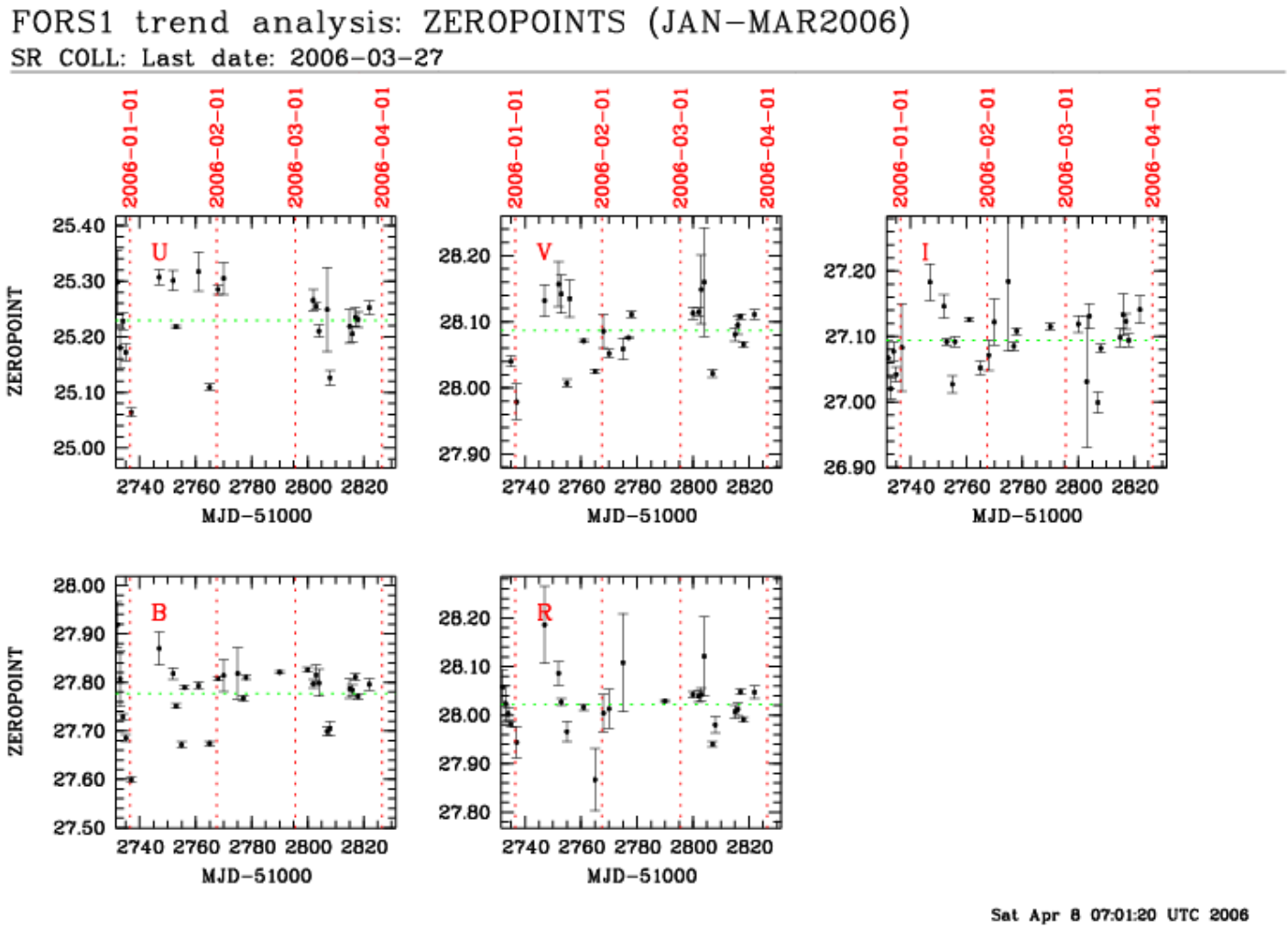
- FORS: ESO‘s visual and near UV FOcal Reducer and low dispersion Spectrograph for the Very Large Telescope (VLT) .
- all-dioptric instrument for the wavelength range from 330 nm to 1100 nm and provides an image scale of 0".2/pixel (or 0".1/pixel with the high resolution collimator)
- 2048 x 2046 pixels CCD detector (pixel size of 24 x 24 μm) of FORS1.

Photometry with FORS



FORS deep field

- pl
- tw
- pi
- ze
- tr

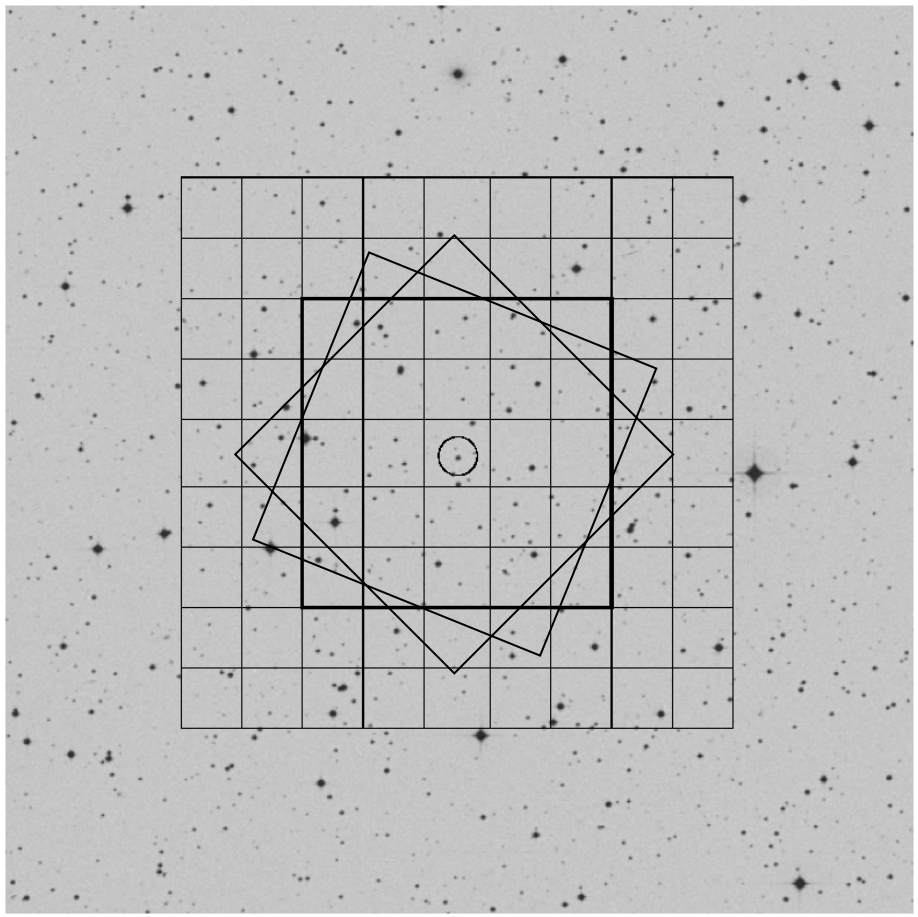


	e		
U	0		
B	0		
V	0		
R	0.13	+0.02	R - r = Zp_R + colour_R * (V-R) - ext_R * X
I	0.09	-0.08	I - i = Zp_I + colour_I * (V-R) – ext _I * X

Photometry Project Goals

- demonstrate 3% absolute photometry with standard resolution collimator
- establish procedures to advise observers
- estimate accuracy of standard calibration procedure

Relative Photometry Test
Data: 1000 points of light



5 x 5 grid

+ 2 rotations

Relative Photometry Test Data

- First data set (FSSWG project):
  - dithered set of R + V band images
  - pairs of images
  - non-photometric
- second data set (FAP project):
  - taken under photometric conditions
  - 10 sec exposure time to avoid shutter problems
  - better sampling: dither 5x5 points
  - includes Stetson standards

Relative Photometry Method

flatfield correction: $f(x,y) = \sum_{i=0}^{k} \sum_{j=}^{o-i} p_{ij} x^i y^j$

$$\mathbf{A} \cdot \mathbf{p} = \mathbf{M}$$

parameters:

$$\mathbf{p} = \begin{pmatrix} p_{0,0} \\ p_{1,0} \\ p_{0,1} \\ \vdots \\ p_{kl} \\ M_1 \\ M_2 \\ \vdots \\ M_n \\ z_1 \\ z_0 \\ \vdots \\ z_m \end{pmatrix}$$

measured relative mags:

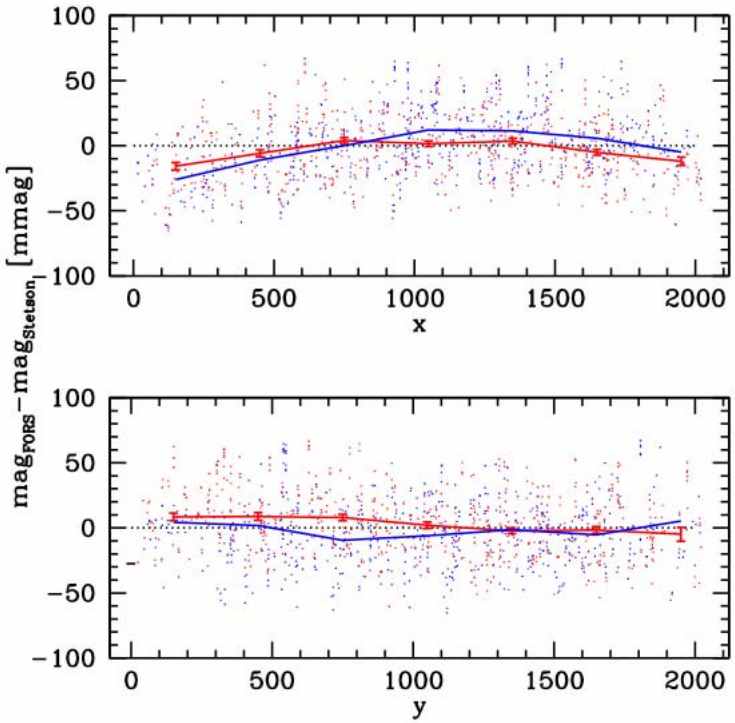
$$\mathbf{M} = \begin{pmatrix} m_{0,0} \\ m_{1,0} \\ m_{2,0} \\ \vdots \\ m_{n,0} \\ m_{0,1} \\ m_{1,1} \\ \vdots \\ m_{n,m} \end{pmatrix}$$

$$\mathbf{A} = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ \vdots \\ n \\ n+1 \\ n+2 \\ \vdots \\ n \times m \end{array} \begin{array}{c} \begin{array}{cccccccccccccc} p_{0,0} & p_{1,0} & p_{0,1} & \cdots & p_{kl} & M_1 & M_2 & \cdots & M_n & z_1 & z_2 & \cdots & z_m \end{array} \\ \begin{pmatrix} 1 & x_0 & y_0 & \cdots & x_0^k y_0^l & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\ 1 & x_1 & y_1 & \cdots & x_1^k y_1^l & 1 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\ 1 & x_2 & y_2 & \cdots & x_2^k y_2^l & 0 & 1 & \cdots & 0 & 0 & 0 & \cdots & 0 \\ & \vdots & & & & \vdots & & & & & \vdots & & \\ 1 & x_n & y_n & \cdots & x_n^k y_n^l & 0 & 0 & \cdots & 1 & 0 & 0 & \cdots & 0 \\ 1 & x_0 & y_0 & \cdots & x_0^k y_0^l & 0 & 0 & \cdots & 0 & 1 & 0 & \cdots & 0 \\ 1 & x_0 & y_0 & \cdots & x_0^k y_0^l & 1 & 0 & \cdots & 0 & 1 & 0 & \cdots & 0 \\ & \vdots & & & & \vdots & & & & & \vdots & & \\ 1 & x_0 & y_0 & \cdots & x_0^k y_0^l & 0 & 0 & \cdots & 1 & 0 & 0 & \cdots & 1 \end{pmatrix} \end{array}$$

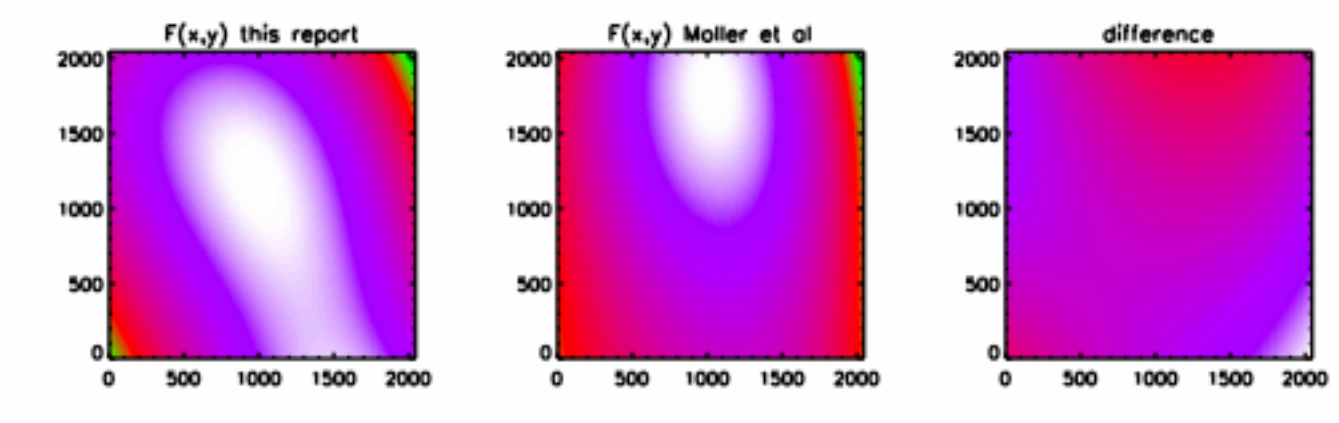
singular value decomposition (SVD):

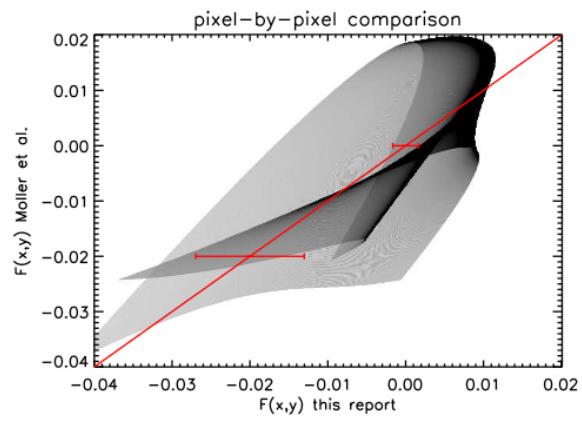
$$\mathbf{p} = \mathbf{v} \cdot \mathbf{w}' \cdot \mathbf{u}^{\mathbf{t}} \cdot \mathbf{M}$$

Relative Photometry Results 1

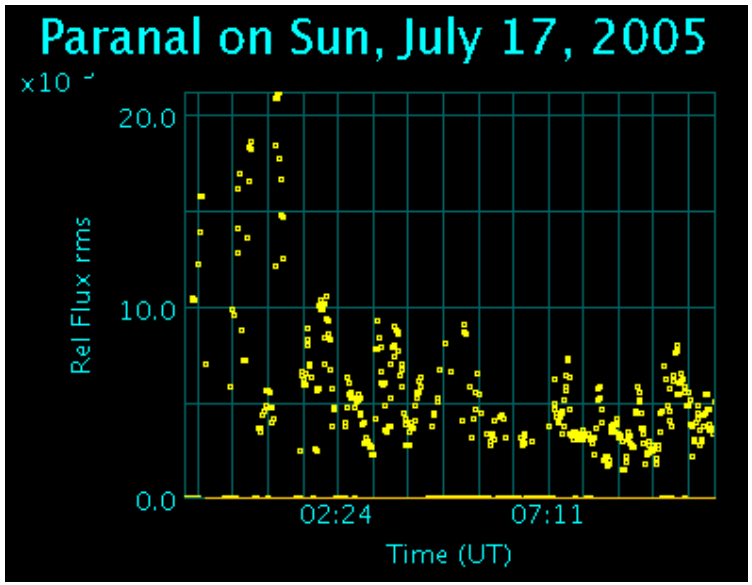


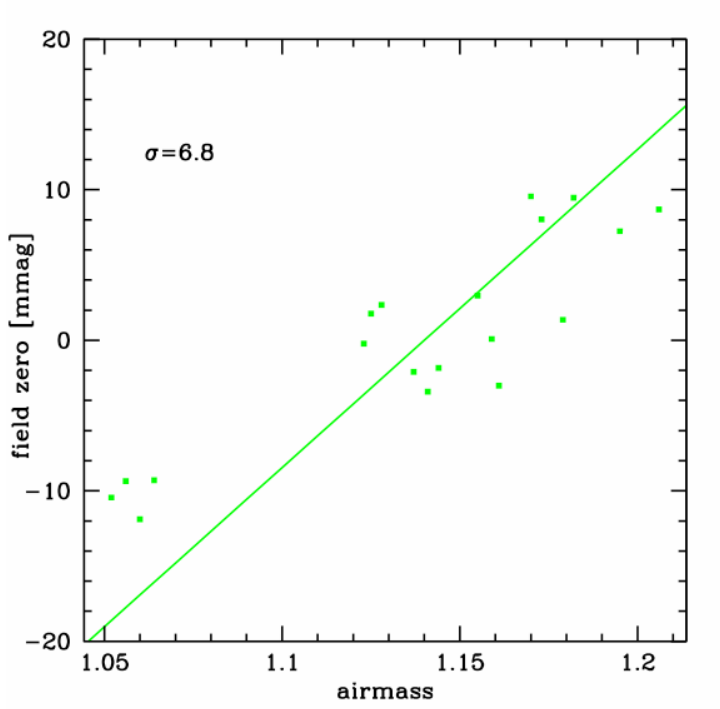
Relative Photometry Results 2





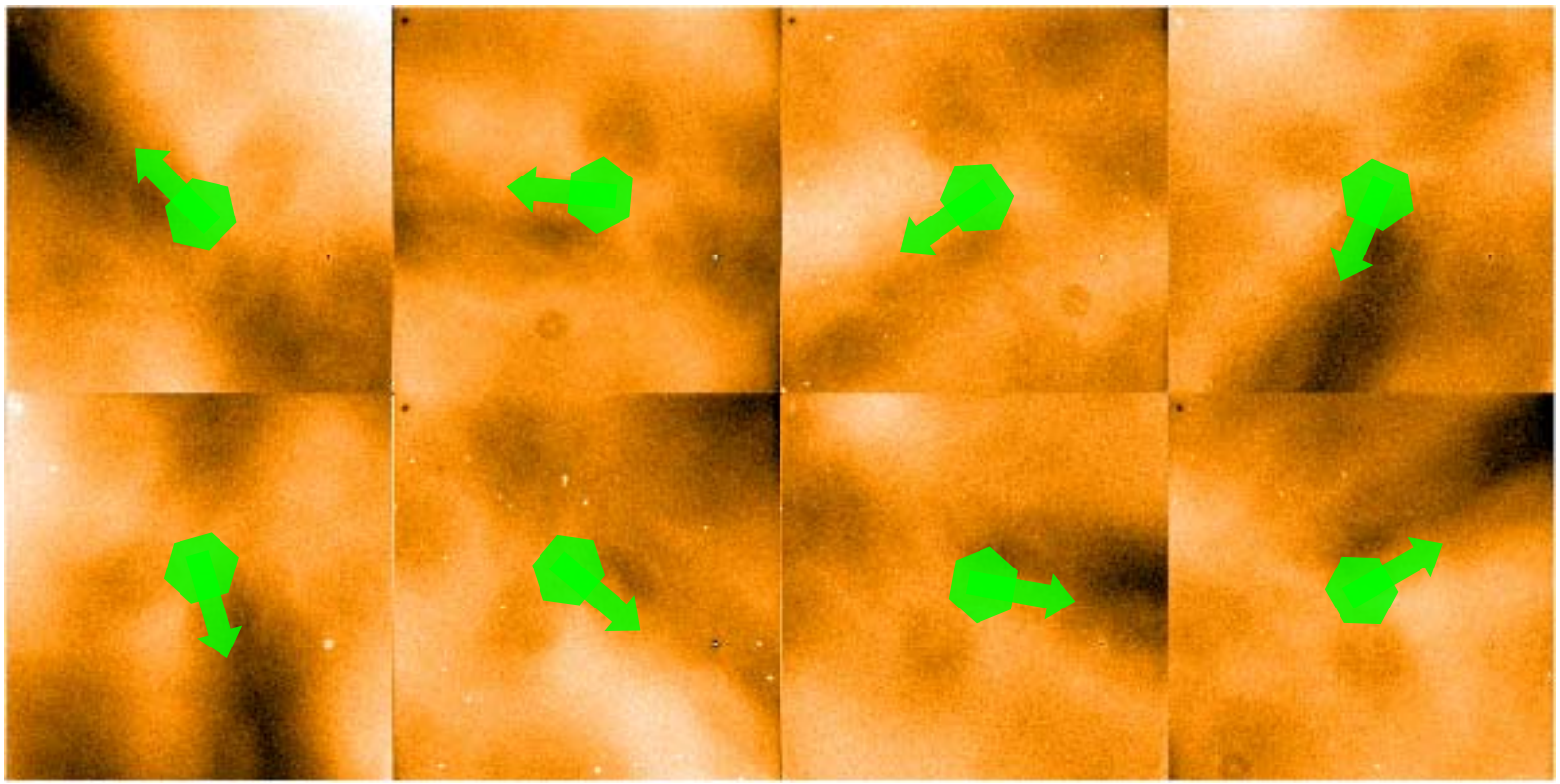
Relative Photometry Results 3



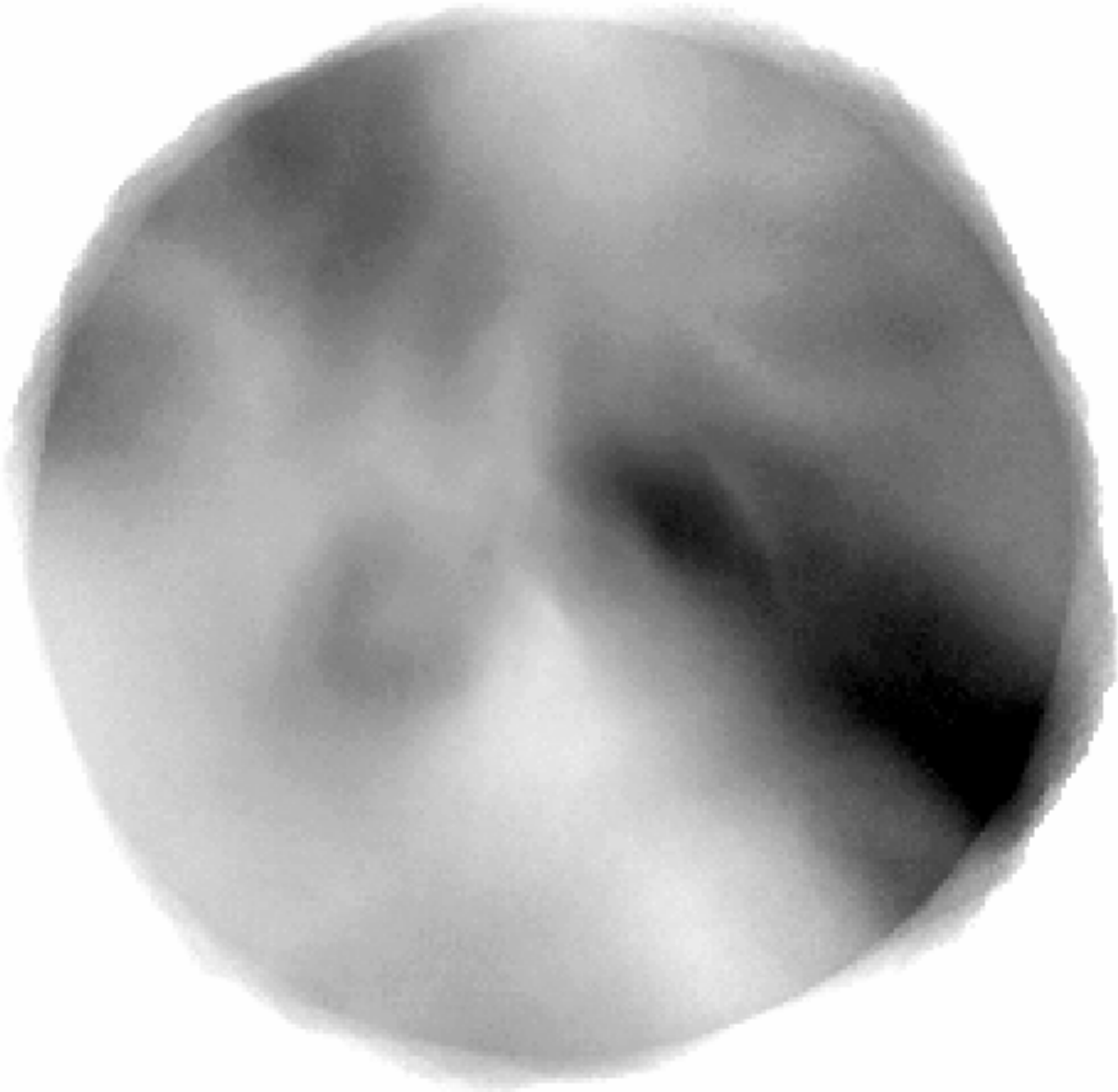


VLT Astronomical Site Monitor

Flatfields and Rotator Angle

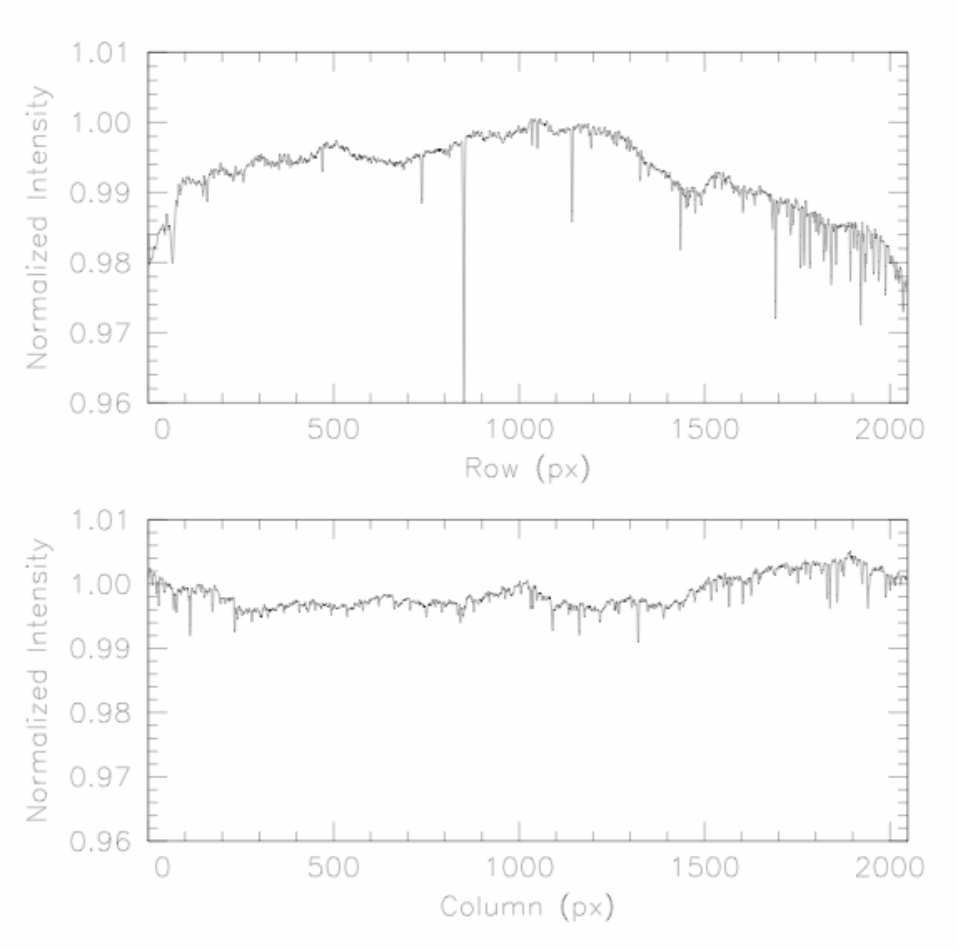


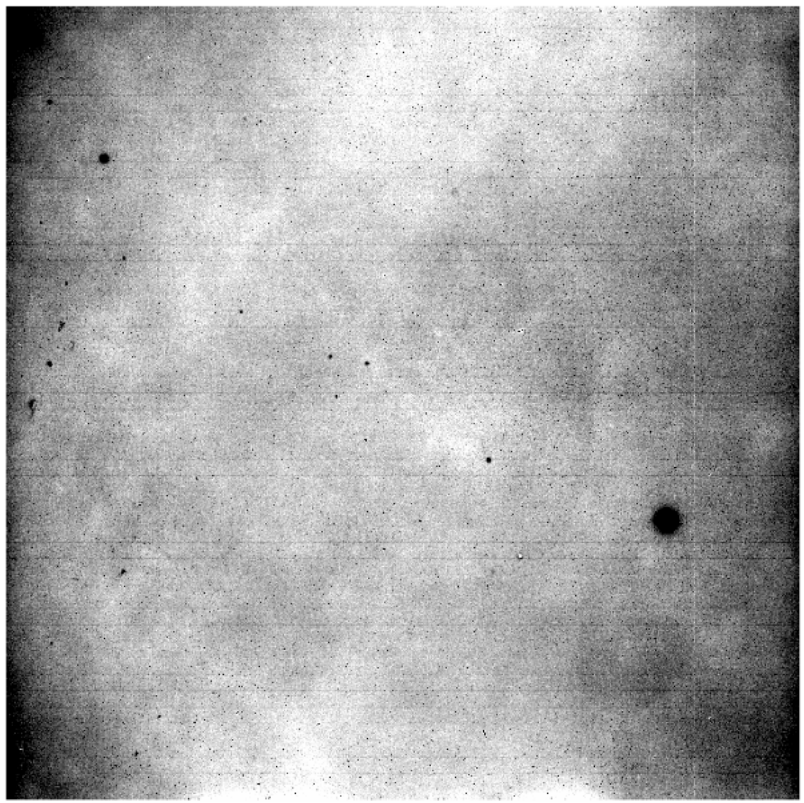
rotator adaptor angle: -185°, -145°, -105°, -73°, -34°, 0°, 30°, 70°



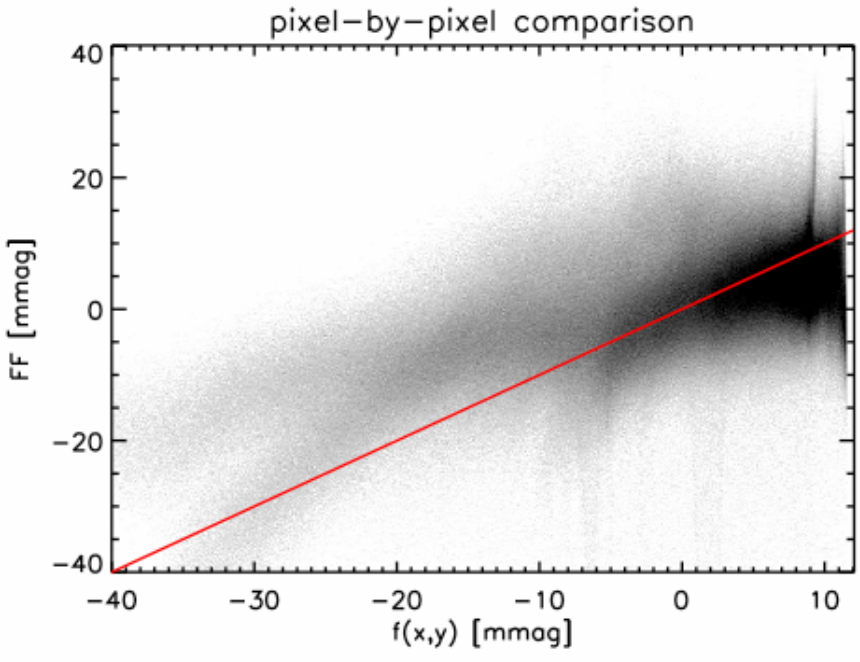
r

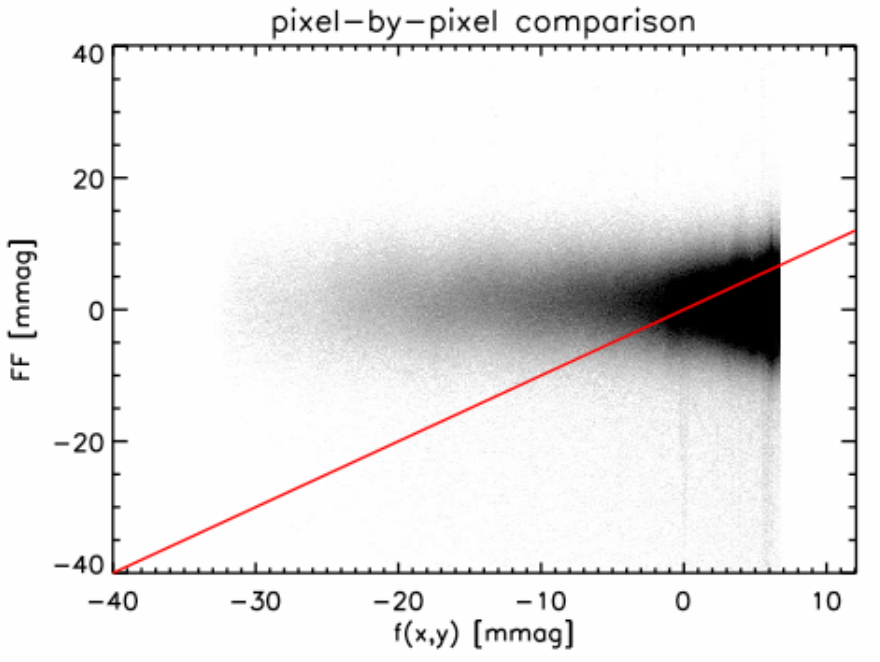
mean of 240 R-band flats - selected to cover all rotator angles uniformely





Pixel-Pixel comparison master flat vs. correction flat



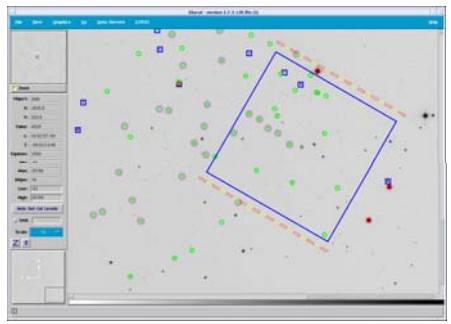


Conclusions: How to do Photometry with FORS

- FORS is photometrically stable to better than 1%
- current “master flats” introduce zero point variations of about 3%. Simply removing the large scale illumination pattern improves flatfielding accuracy.
- New procedure for nightly standard observations includes dither. Nightly photometric zero points are accurate to about <5%
- ASM monitor useful as indicator of photometric stability
- to obtain photometric solution, observers need to sample zero point at different airmasses, will be charged to observing program

Status of Implementation

- Ongoing:
  - Selection of new Standard fields based on Stetson fields.
  - Implementation of the observing procedure (OBs) for standard observations



- Soon:
  - Test of procedure
  - Secondary Standards for U band

- Later:
  - New Pipeline to produce nightly zero will include new procedures
  - New procedure for users to request standards