Image Quality from VLT Instruments

(Sabine Moehler, October 7, 2008)

1 General Status

As of October 2008, instruments which monitor image quality are ISAAC, FORS1/2, NACO, and VIMOS. Of those NACO operates solely with adaptive optics and is therefore omitted from this study.

2 Optical instruments: FORS1/2, VIMOS

2.1 Summary

The optical instruments use SExtractor to obtain the source parameters. They do apply somewhat different selection criteria to determine the actual image quality and to guard against outliers (see below for details). Due to their selection criteria the FORS results are probably more robust against problems with guiding. So from the way the values are determined one would not expect to see differences between the FORSes and VIMOS. However, a spot check with R band data from the past 12 months (excluding September 2008, when VIMOS had a focus problem) shows that there are systematic differences between the instruments. VIMOS Q1 data in general show a worse image quality and higher ellipticity. A plot of the image quality vs. the DIMM seeing (see Fig. 1) shows that VIMOS obviously observes at worse DIMM seeing than the FORSes.

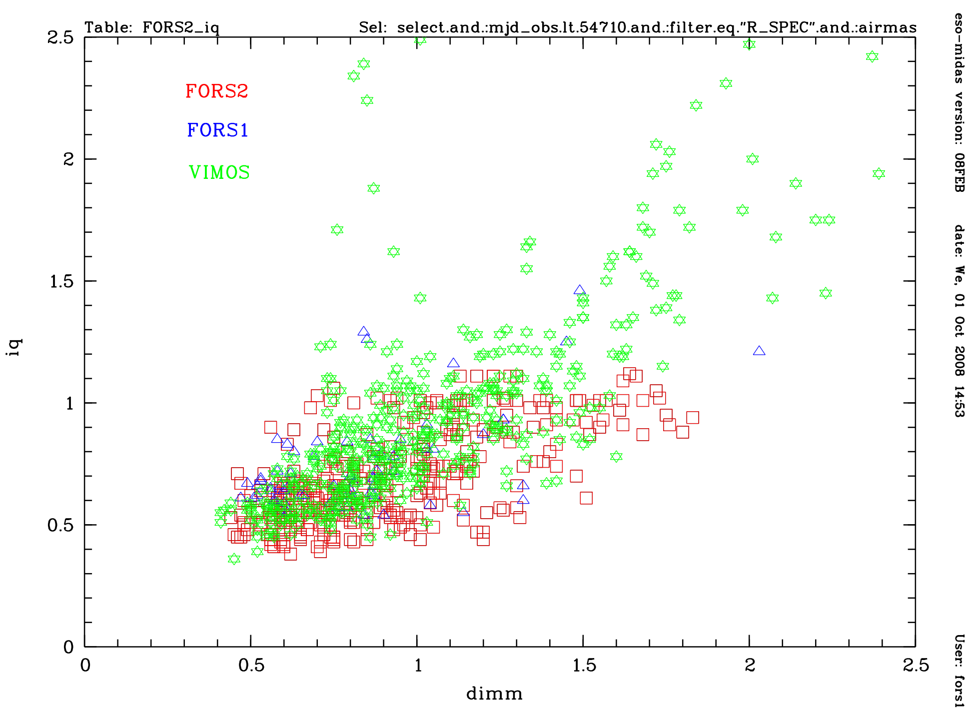

Figure 1: Optical image quality versus uncorrected DIMM seeing

However, the VIMOS data follow the trend set by the DIMM to values above 1.″5, whereas the FORS2 data level off (FORS1 has too few data points to allow any statement).

There are no obvious differences between FORS1/2, which is expected since the instruments are identical with respect to imaging and the same software and selection criteria are used.

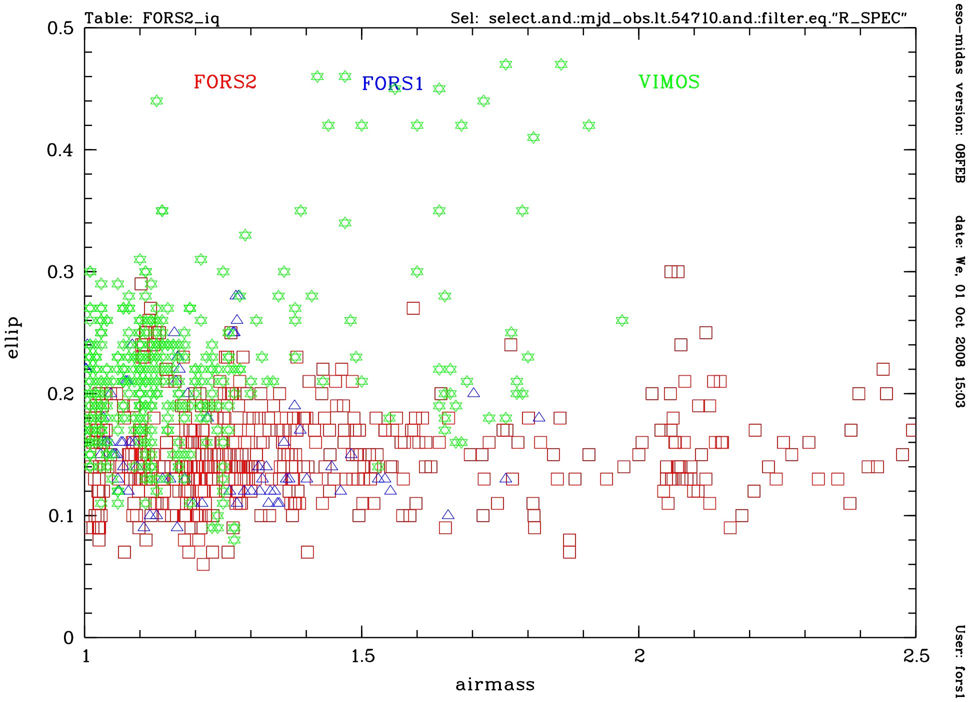

Figure 2: Ellipticity versus airmass

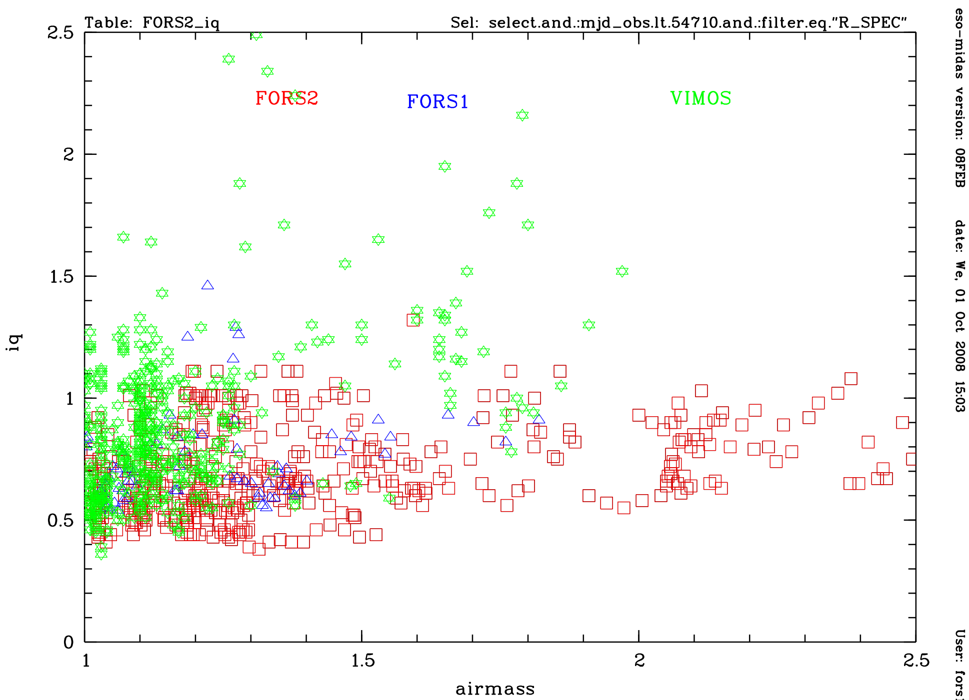

Figure 3: Optical image quality versus airmass

2.2 Possible Causes for the Differences between FORS1/2 and VIMOS

There are two obvious differences between VIMOS and the FORSes:

1. VIMOS has a much larger field-of-view (about $16' \times 18'$) than the FORSes (about $7' \times 7'$) and thus a larger maximum distance from the optical axis of the telescope. The radial degradation of the image quality from the telescope is overlayed by the separate optics for each VIMOS quadrant, whereas the FORS optics is centered on the center of the field-of-view.

Markus Kissler-Patig (Garching instrument scientist for VIMOS) provided results of image quality test measurements (using a pinhole mask) from the VIMOS commissioning that show that the image quality degrades significantly outside an area of about 500×500 pixels within each quadrant (this area not being in the same place for all quadrants). Burkhard Wolff (QC scientist for VIMOS) also mentioned that it is not possible to put all quadrants simultaneously at the best focus.

During FORS1 commissioning such data were unfortunately not observed. Instead the image quality was checked during periods of good seeing and was found to degrade only marginally from the center to the edge of the field-of-view. During FORS2 commissioning a pin-hole mask was used, which shows at most 10% of variation in the image quality across the field-of-view.

2. VIMOS does not have an Atmospheric Dispersion Compensator. While VIMOS observations are usually obtained at low airmass, there are data points at higher airmass that usually have a rather high ellipticity and bad image quality (see Figs. 2 and 3). Atmospheric refraction alone, however, cannot explain the discrepancy between VIMOS and the FORSes as it persists to lower airmass, albeit at a reduced level (cf. Fig. 4).

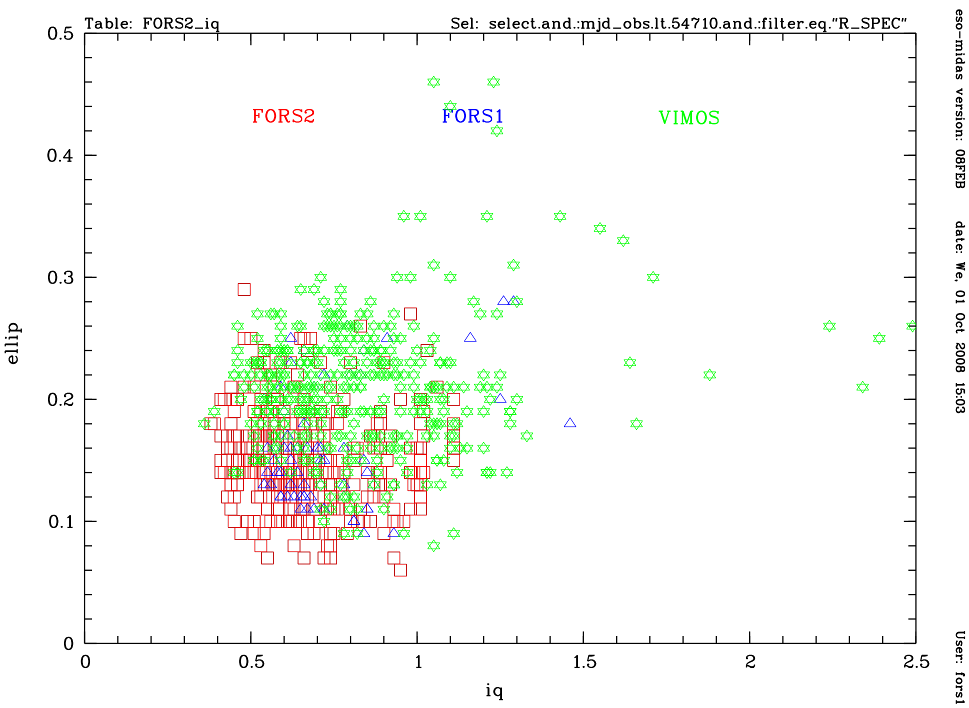

Figure 4: Ellipticity vs. optical image quality for airmass below 1.5

Due to these discrepancies one should not attempt to combine VIMOS and FORS data to get a better coverage.

2.3 Monitored Parameters

The **image quality** is determined only from objects that have been classified as stars (stellarity index > 0.5). The FORSes require in addition an ellipticity of less than 0.5 and the quality flag from SExtractor to be 0, i.e. they are more strict in their selection and may therefore miss outliers from bad guiding or other problems. VIMOS requires that at least 10 stars were identified, whereas the FORSes enforce this only for trending, not for storing the values.

When calculating the **error of the image quality** all instruments use some mechanism to reject outliers: VIMOS rejects anything outside of 3σ, whereas the FORSes use a symmetric range

|mode_seeing – minimum_seeing| on both sides of the mode seeing ("core of the distribution") to estimate the error, thereby cutting off just outliers with large values of image quality.

VIMOS calculates the **ellipticity** using all stars, whereas the FORSes use only stars within the so-called core of the distribution (symmetric range |mode_seeing – minimum_seeing| on both sides of the mode seeing) and exclude anything with an ellipticity above 0.5. The FORSes are therefore biased against outliers, e.g. from the edges of the field.

The FORSes log wind speed and direction with their rms from the **ambient data** database. VIMOS in addition provides humidity, pressure, and focus temperature.

3 Infrared Instruments: ISAAC

3.1 Summary

Plotting the ISAAC image quality data obtained with filtering against extended objects vs. DIMM seeing shows very similar trends for FORS1/2 R band data (converted to the ISAAC filter bands) and the ISAAC data (see Figs. 5, 6, and 7).

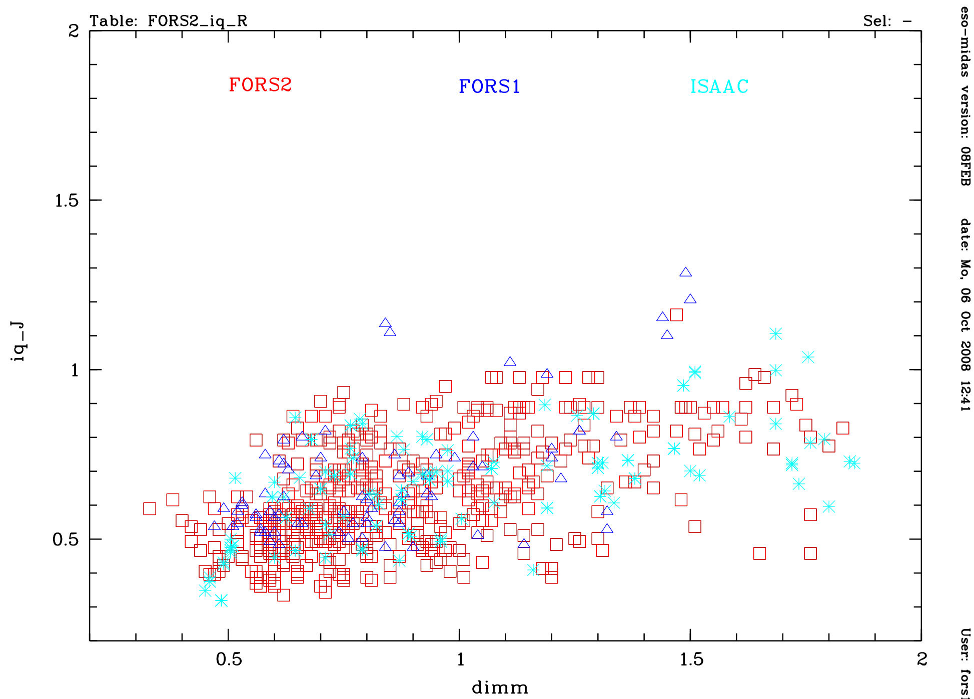

Figure 5: J Image quality vs. uncorrected DIMM seeing

3.2 Monitored Parameters

ISAAC provides three types of image quality with different outlier rejection mechanisms:

qc_iq average image quality (in arcsec) in co-added images with *filtering of extended sources*: all sources for which one of the two fwhm_x, fwhm_y values is above 5.″0 or below 0.″1 are excluded and all sources for which |fwhm_x – fwhm_y| > 0.″2 are excluded

qc_fwhm_ac median FWHM (in arcsec) of *all sources* to allow to verify the filtering of extened objects

qc_mode mode of the FWHM distribution in arcsec. This parameter has been calculated by the pipeline since 2007 and apparently has some problem, as it yields values below 0.″2. The problem is currently under investigation. The values from earlier years look ok.

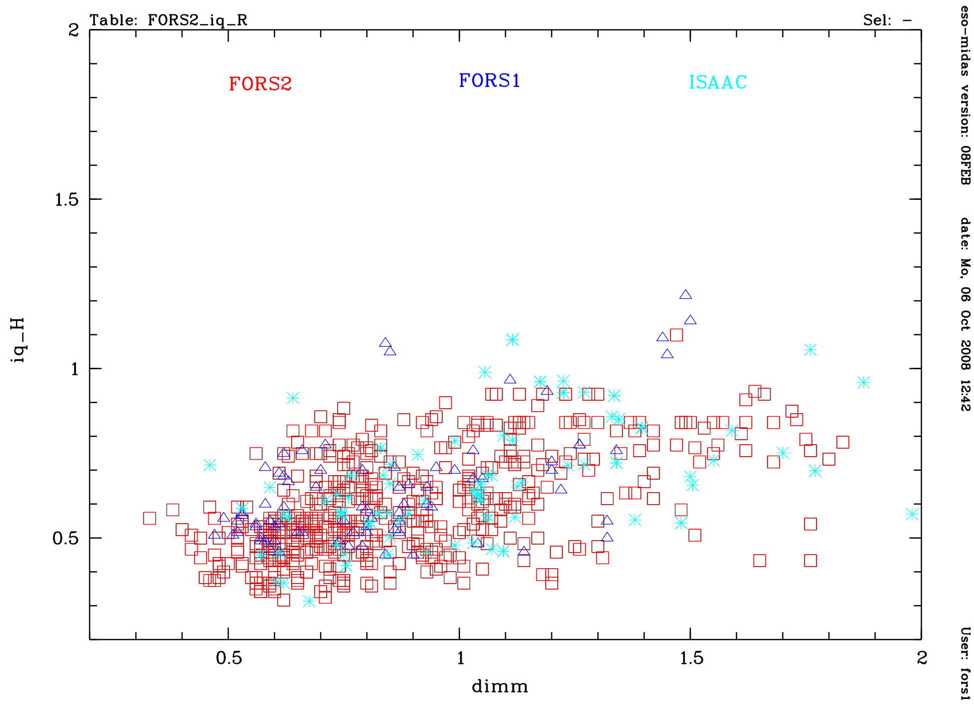

Figure 6: H Image quality vs. uncorrected DIMM seeing

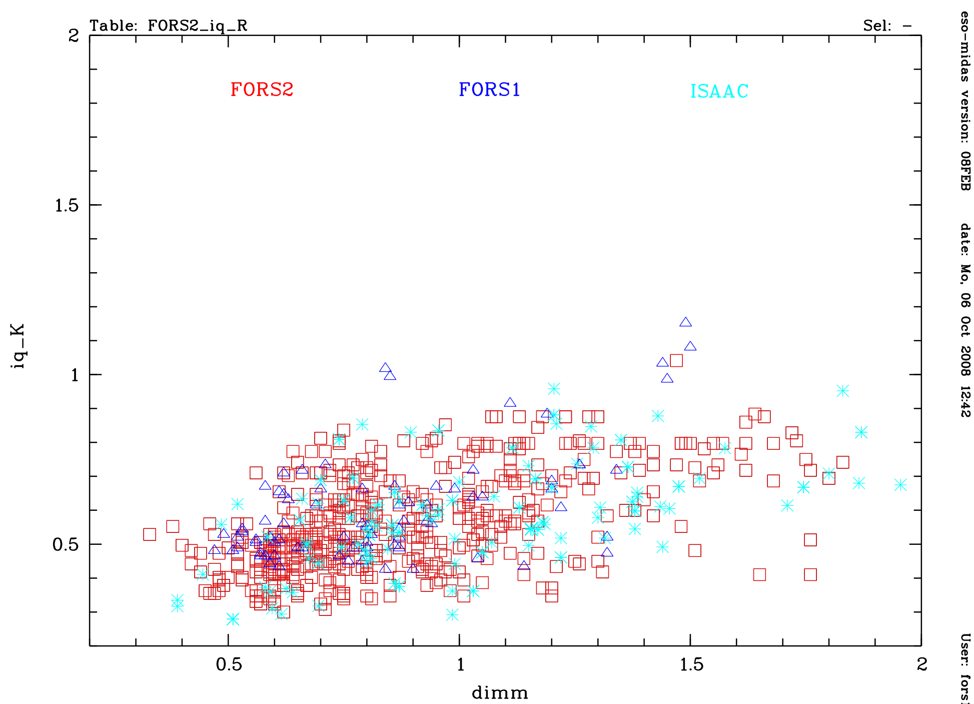

Figure 7: K Image quality vs. uncorrected DIMM seeing

qc_fwhm_ac and qc_iq show a very tight correlation with few outliers:

$$\text{qc\_iq} = (0.91\pm0.01) \cdot \text{qc\_fwhm\_ac} + (0.04\pm0.01)$$

with an rms of 0.05. In order to compare ISAAC and FORS1/2 data I used qc_iq for ISAAC and the wavelength corrected value $\text{iq}_{\text{FORS}}^{\text{ISAAC}}$ of iq from FORS1/2:

$$\mathrm{iq}_{\mathrm{FORS}}^{\mathrm{ISAAC}} = \mathrm{iq}_{\mathrm{FORS}} \cdot \frac{\lambda_{\mathrm{FORS}}}{\lambda_{\mathrm{ISAAC}}}^{0.2}$$

Plotting the image quality data vs. DIMM seeing then shows very similar trends for the converted FORS1/2 R band data and the ISAAC data.

The FORSes log wind speed and direction with their rms from the **ambient data** database. VIMOS in addition provides humidity, pressure, and focus temperature.

ISAAC logs wind speed and azimuth, angle between wind azimuth and telescope azimuth, time difference between wind measurement and ISAAC observation, ambient temperature and humidity.