Towards a Deep IR ESO Sample

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As soon as the near-IR arrays became available, various observatories started to experiment with infrared cameras in order to achieve high-accuracy two-dimensional images in the near-infrared. The work of ESO in this field has been briefly illustrated by Morwood *et al.* 1992).

Cowie (1991) showed that the counts of galaxies in the K′ magnitudes were in disagreement with the counts obtained in the blue band in the sense that, in this colour, we would not measure the large excess of faint galaxies observed at shorter wavelengths. The observed difference in the counts is obviously deeply connected also with the understanding of galaxy evolution since (a) in the blue we are detecting objects which we obviously do not see in the near-IR and (b) we should be able to understand which kind of objects are causing such a difference and at which redshifts they are, i.e. intrinsically faint and at low-medium redshift or intrinsically bright and far away. Merging among field galaxies could explain in part the observed dichotomy (Broadhurst *et al.*, 1992). However, more observations of deeper samples are extremely important to understand what is going on. Indeed, it is fundamental, also in relation to the new class of very large telescopes, to be able to have catalogues of faint and distant objects in order to study the detailed properties of galaxies at large redshifts.

In this paper we will briefly describe the accuracy achieved in data reduction of the fields we observed in the IR using IRAC2 (NICMOS III array) at the 2.2-m telescope of ESO. The project aims at galaxy counts in the K′ band and to the preparation of a faint-object catalogue for detailed studies. The full analysis, the details of the reduction procedure and the science results will be the subject of a later publication.

The sample had been selected according to the following criteria: (a) it had to cover a large area, (b) it had to go deep enough to be significant for counts of galaxies statistics and form, in any case, a catalogue on which to base the spectroscopic observations of faint non-cluster galaxies, and (c) its field had to be selected at high galactic latitude to minimize the extinction. In addition, and due in part to the limitations in the setting of the telescope and to the suggestions by Morwood, all fields had to include a medium-brightness star, about 14th magnitude, in order to optimize the stacking of the different IR frames. Having in mind this recipe, we searched the sky around the southern galactic pole for UK-ESO blank fields of $\sim 2 \times 2$ arcmin (which is about the size of the CCD on the focal plane of the 2.2-m telescope) with either one or two stars with magnitude in the range 13–15. At the moment of the observations we preferred to select fields with two stacking stars. This would give a very accurate reference for stacking of observations obtained in different observing years. The strategy we adopted, due also to some unknowns about the final performance of the array and the reduction procedure, was to select 3 fields on which to go deeper, down to K′ $\approx$ 20.0, and 8 fields for which we planned a shallower limiting magnitude with the purpose of having a good statistics at somewhat brighter magnitudes. This is the only sample of faint galaxies selected in the K′ band done at ESO and consists of 11 fields of 2.8 arcmin^2. This sample and its analysis will give us also accurate information on the limiting magnitude we can reach, by increasing the number of observations, within a reasonable amount of telescope time.

Linearity

Images were obtained at the telescope using all the integration times which were feasible without saturating the chip, in the K and K′ band. In practice, the integration time varied between 0.882 and 4.155 sec. We tested then the CCD as a whole and its four 128 × 128 quadrants. The result is that each quadrant, and the CCD as a whole, has a linear response[1] with

[1]The linearity of the detector can be defined according to the relation:
$L = \sqrt{l/n\Sigma[l - N_i^{real}/N_i^{ideal}]^2}$
where n is the number of measurements obtained in that range and N_i^{real} and N_i^{ideal} are the expected and measured counts.

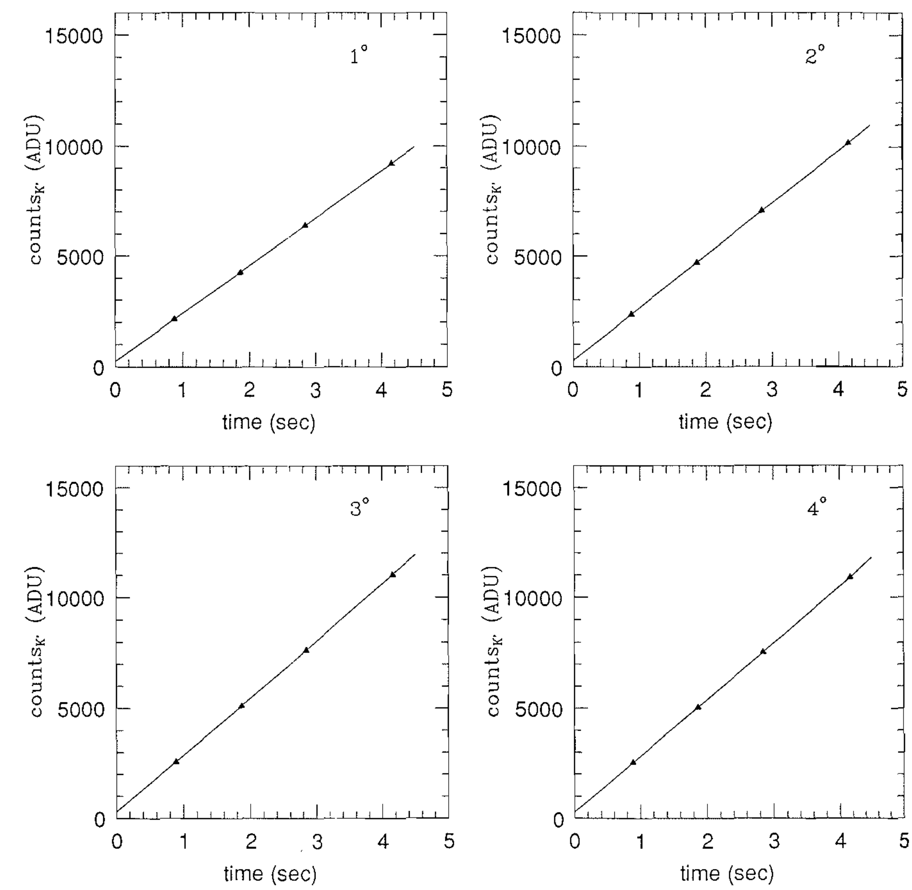

Figure 1: *Linearity test on the 4 quadrants of the NICMOS III array.*

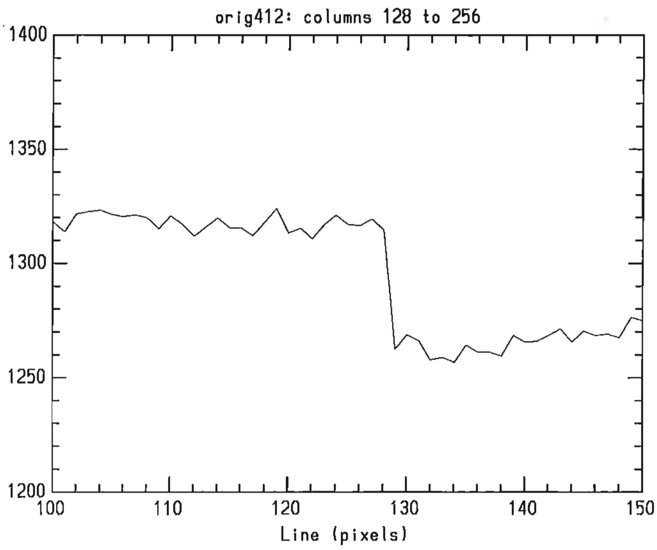

Figure 2: *Sensitivity difference between the two halves of the array.*

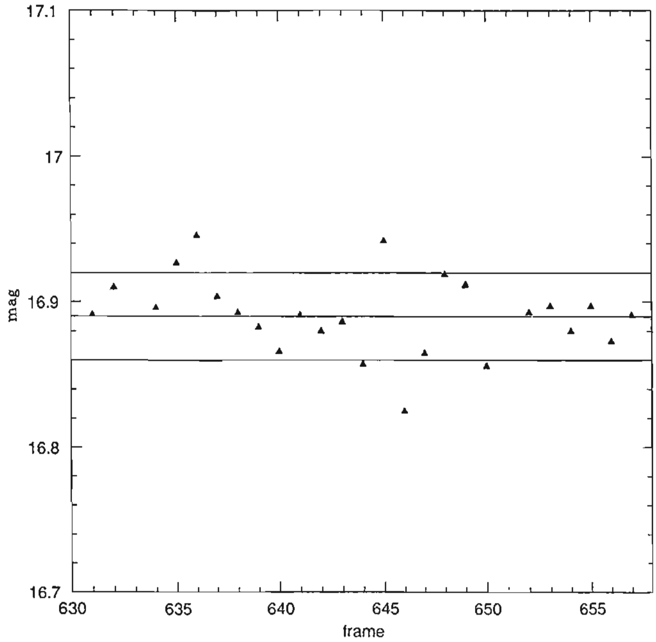

Figure 3: *Magnitude of one of the "stacking stars" measured in 25 different frames.*

a deviation from linearity smaller than 5 10^{-3}. The slope differs, however, from quadrant to quadrant, Figure 1, with the main difference being beetween the upper and lower half, Figure 2. This effect, which is present also on smaller scales and amounts to about 1 %, is corrected by dividing the images by the FF.

Flat Field (FF)

A variety of tests have been done in order to optimize the S/N of the reduced images, both using dome and sky flats. The optimum procedure resulted in constructing the flat-field image for each frame from the median of the adjacent sky images. The selection criterion, among the different methods, has been based on the minimization of the error estimated on the standard stars which have been observed on each quadrant of the CCD array. The rational of using a small group of adjacent sky frames ($\sim$ 9) is that (a) by using the whole set ($\geq$ 27 frames per field of two minutes each) we would be sensitive to long-period sky variations, and that must be avoided and (b) by using a small number of adjacent frames we smooth out the small-period sky variations which may affect each single frame in a rather random way. To each target frame is then assigned its own flat field.

For these stars we also measured their profile. The aperture used to determine the magnitude is that for which the magnitude derived is the same, within the error, as the magnitude measured using the next larger aperture.

The Zero Point

After applying the FF correction described above, for the images of the standard stars (each star was imaged in each frame on the 4 quadrants) we measure as typical values: σ(1st night) = 0.04 mag, σ(2nd night) = 0.033 and σ(3rd night) = 0.035.

The K′ zero point of our photometry was derived using the relation

$$K' - K = 0.20\ (H–K)$$

and the K′ zero point error for the standard stars on each single night was: σ_0(1st night) = 0.04, σ_0(2nd night) = 0.02

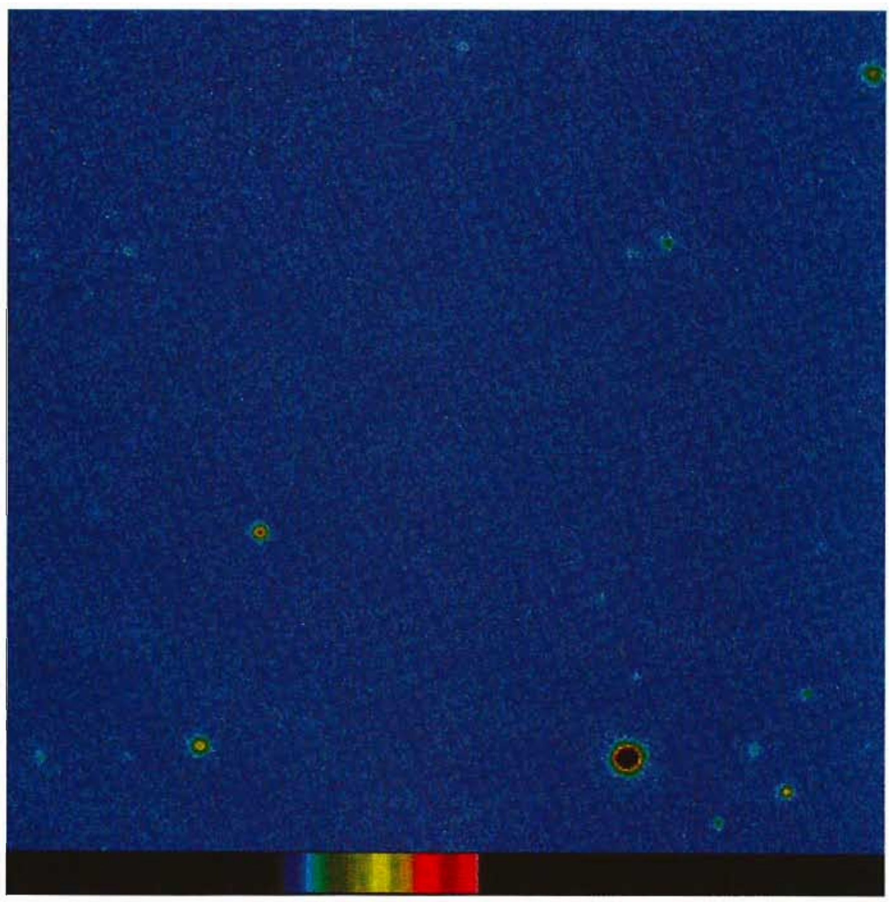

Figure 4: *Image of one of the deep fields. Integration time is 162 minutes. The faintest objects visible are of m $\sim$ 20 in K′.*

and σ_0(3rd night) = 0.03. As a check of the quality of our photometry we measured the magnitudes of the stacking stars we had on the target frames, the run of magnitude versus frame number is illustrated in Figure 3 and shows perfect agreement with the estimates given above.

Note that the Poisson photon noise due to the sky (gain factor = 5.2) is estimated to be of 0.01 mag so that the accuracy attained is close to the theoretical limit expected and shows that with IRAC2 it is possble to achieve high-accuracy photometry. A target frame, deep exposure, has been reproduced in Figure 4.

Acknowledgements

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References

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