Comments on faint galaxy surveys — Ground vs. NICMOS Camera 3 performance issues

Bob Fosbury — with input from Alan Moorwood, February 1999

Introduction

- Notes on the comparison of 8m groundbased IR imaging and survey spectroscopy with NICMOS
- Based on early experience with ISAAC on the ESO VLT
- Intended as a generic comparison, not ISAAC-specific

Topics

- Basic summary of ISAAC
- Relevant performance characteristics — FOV, image size and background
- Source sensitivities
- Efficiency for imaging surveys

Summary

For faint galaxy photometric imaging surveys at H-band (F160W), large-format detectors on 8–10m groundbased telescopes are comparable or somewhat faster than NICMOS camera 3 to a given magnitude limit. For K-band surveys, the groundbased telescopes are clearly superior.

For low resolution spectroscopic surveys, the NICMOS grism mode is currently unique in providing multi-object spectroscopy to faint limits (see the Parallel results from McCarthy et al. 1999). However, recent tests at Paranal have shown a very low sky brightness between the OH lines which implies that groundbased slit spectroscopy could be very fast at a resolution sufficient to measure between the OH.

ISAAC

VLT *Infrared Spectrometer And Array Camera*

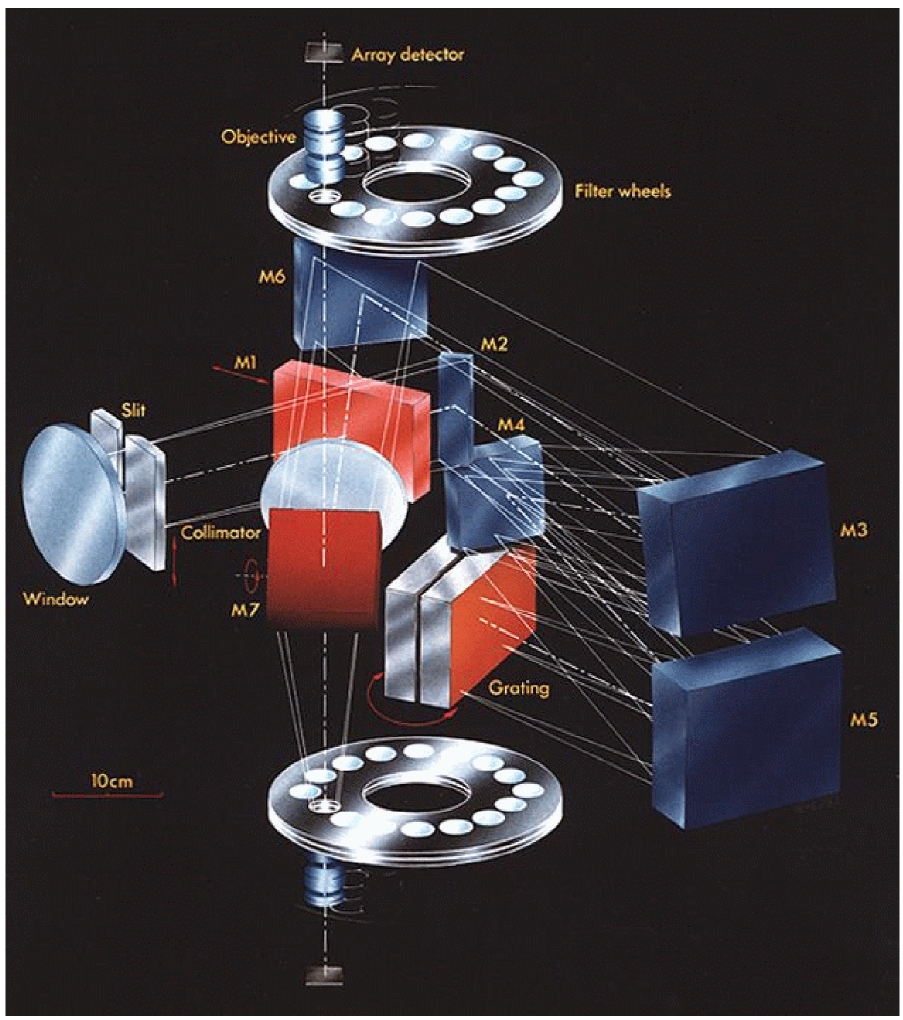
Covers the wavelength range 1–5µm (SW and LW channels) and is designed primarily for:

'Wide' field imaging (max. 2.5 x 2.5 $arcmin^2$)

Long slit low (Rs ~ 500) and medium resolution (Rs ~ 3000) spectroscopy

For the SW channel, the detector is a Rockwell Hawaii 1024x1024 pixel Hg:Cd:Te array and the pixel scale is 0.147 arcsec $pixel^{-1}$

Optical Layout



Comparison of basic data

		ISAAC SW	NICMOS 3
Detector		Rockwell Hawaii 1024 x 1024 Hg:Cd:Te	Rockwell 256 x 256 Hg:Cd:Te
FOV (arcsec^2)		150 x 150	51.2 x 51.2
	ratio	8.6	1
Pixel (mas)		147	200
Broad	J; F110W	16.2	21.1 (0.71)
band	H; F160W	14.3	21.86 (0.65)
backgrounds *	Ks; F222M	12.8	14.15 (58)
Dark current (e^-/sec/pixel)		0.3 (now 0.01)	< 0.03
Read noise (e^-/pixel)		< 10	30
Gain (e^-/ADU)			6.5

** mag(Vega)/arcsec^2 (e^-/sec/pixel)*

Sky brightness

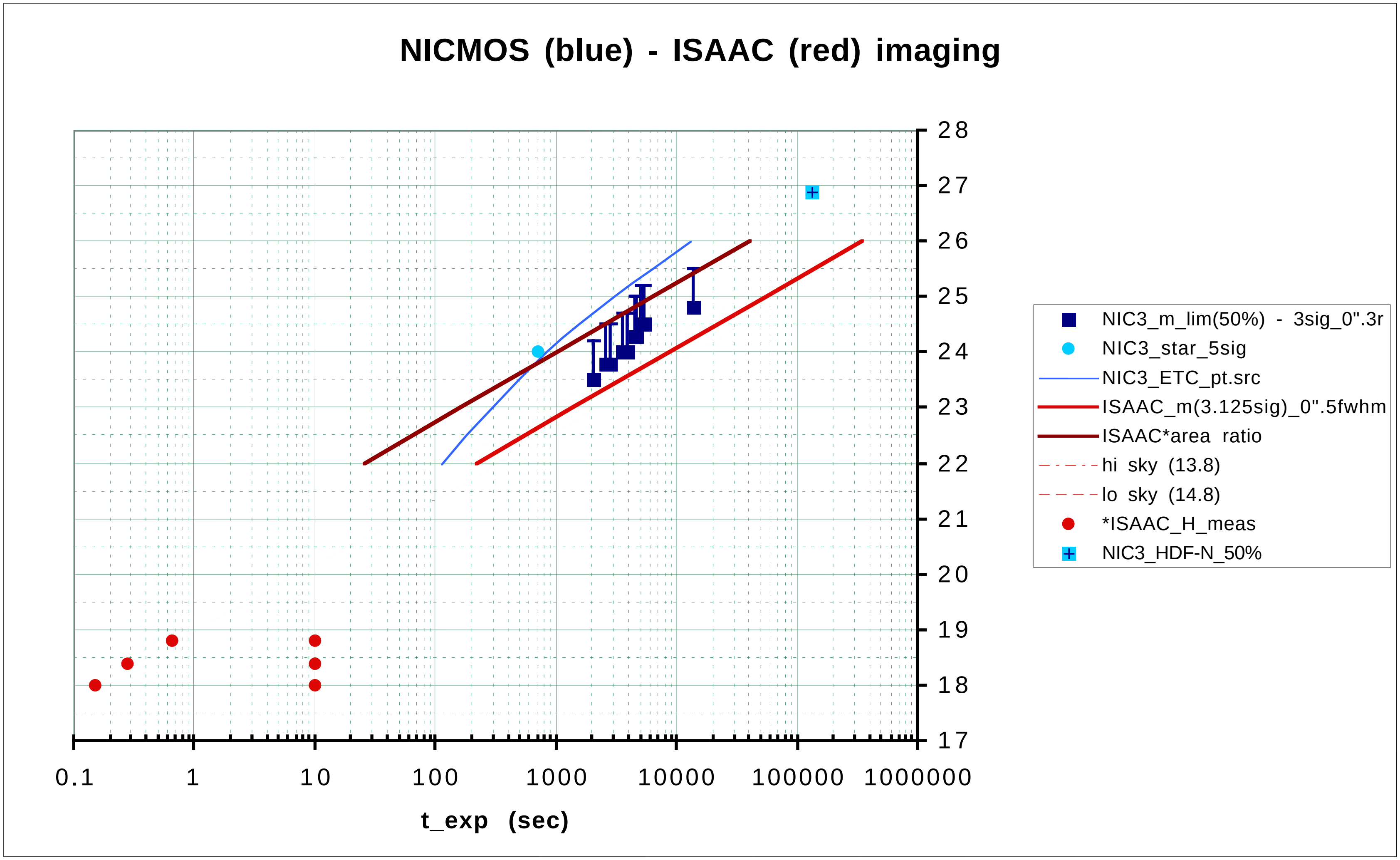
Broad Band Filter Sky magnitude (mag/arcsec^2)

J 16.2; H 14.3; Ks 12.8 — Average

These are quite variable in Chile

J 15.7; H 13.8; Ks 12.3 — Bright

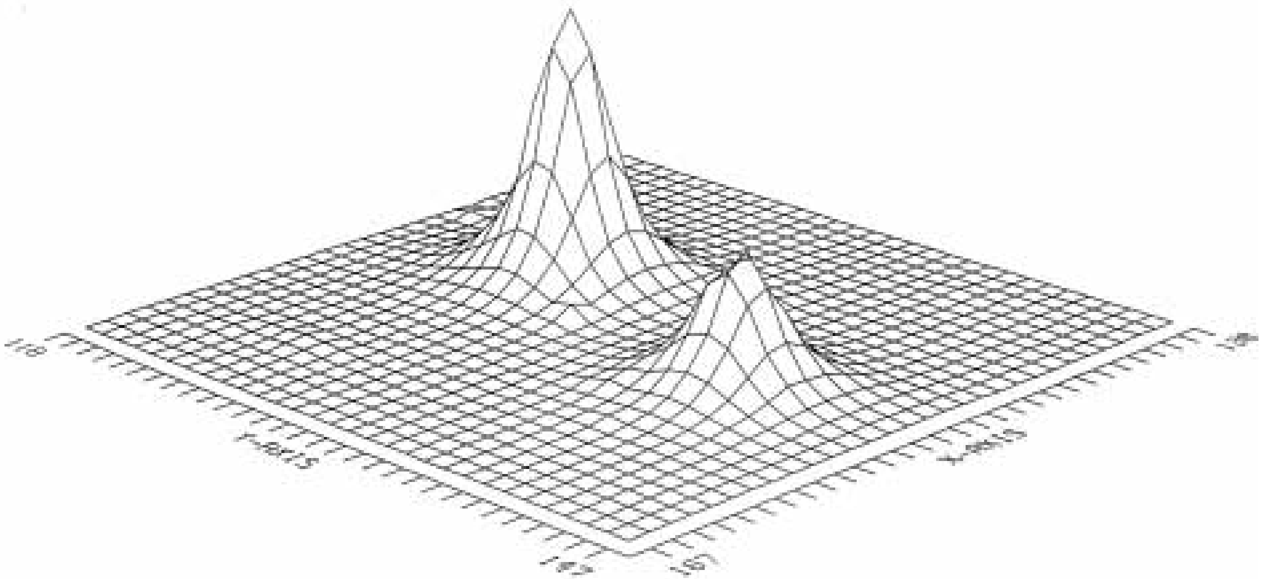
J 16.7; H 14.8; Ks 13.3 — Dark



Comparison of NIC3 with the wide field camera of ISAAC at H-band (F160W). The blue points are various NICMOS measurements from the Public Parallel Survey (Yan et al. 1998, ApJ. 503, L19; from the HDF-N (Thompson et al. 1999, AJ. 117, 17) and a typical star from G. De Marchi (1999, priv. comm.). The galaxy measurements from the first two papers are 50% completeness limits for extended sources; 3-sigma limits are represented by the vertical extensions to the Yan et al. points.

The ISAAC exposure time calculator estimates have been checked with stars measured from a 10sec exposure commissioning image taken with a sky brightness of 13.3 (red points shifted to 3-sigma - thanks to Joao Alves). The dark red line represents the ISAAC 3-sigma sensitivity limit (for an average sky brightness at an air mass of1.2) shifted to the left by the FOV area ratio.

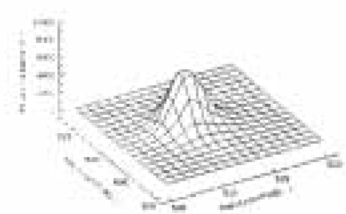
ISAAC imaging performance



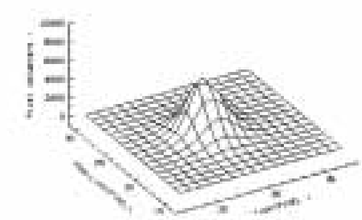
ISAAC 3.8μm FWHM = 0.28", Sep. 1"

Field Stabilization in K
Off Chip (CCD) and On Chip (IR)

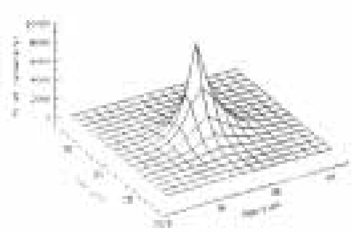
CCD: M2 stabilization off



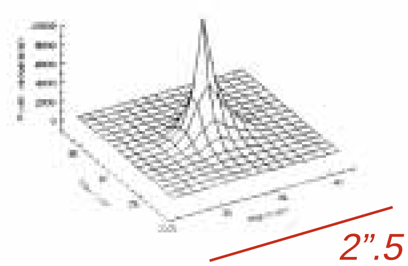
M2 stabilization on



IR: Shift and add



Shift and add & image selection (25%)



VLT + ISAAC

Appendix

Notes from Alan Moorwood

Broad band imaging.

With ISAAC we expect s/n = 5 in 1 hr with 0.5" seeing of J~24, H ~23, Ks=22 (Johnson mags., add 1.86 at K for AB and, if I remember correctly, 0.8 at J).

Medium/low resolution spectroscopy (R ~ 3000–500)

In the recent tests here we have measured a continuum between the OH lines of only ~ 0.1 e/s, we have dark current of ~ 30 e/hr and read noise of a few e. Total noise in a 900s exposure is ~10e. This is a factor ~ 2 lower than currently in the ETC. Noise on ground is thus likely to be lower or equal to NICMOS (which I believe has higher dark current and read noise). As ISAAC has x16 pixels we can consider OH avoidance and re-binning to lower resolution for comparison. Basically, if the noise is the same then ISAAC gains in s/n by the area VLT/HST = 12 or in time by 144. This is not exact because ~ half the spectral range is lost due to the OH. I also do not know the NICMOS spectral resolution and coverage. We have not yet demonstrated we can do this either but SUBARU will have an OH suppression spectrograph yielding R=100 at the end.

Line flux limits in ISAAC MR mode are a few x10^{-17} erg cm^{-2} s^{-1} at s/n = 5 in 1hr.

Based on fairly fundamental arguments, however, it seems probable that groundbased spectroscopy should be ~ 100 x faster than with NICMOS.

Another comparison can be made with the ETC values for the ISAAC low resolution mode which represents the worst case of no OH avoidance or suppression.