Performance of secondary guiding for HARMONI: preliminary results

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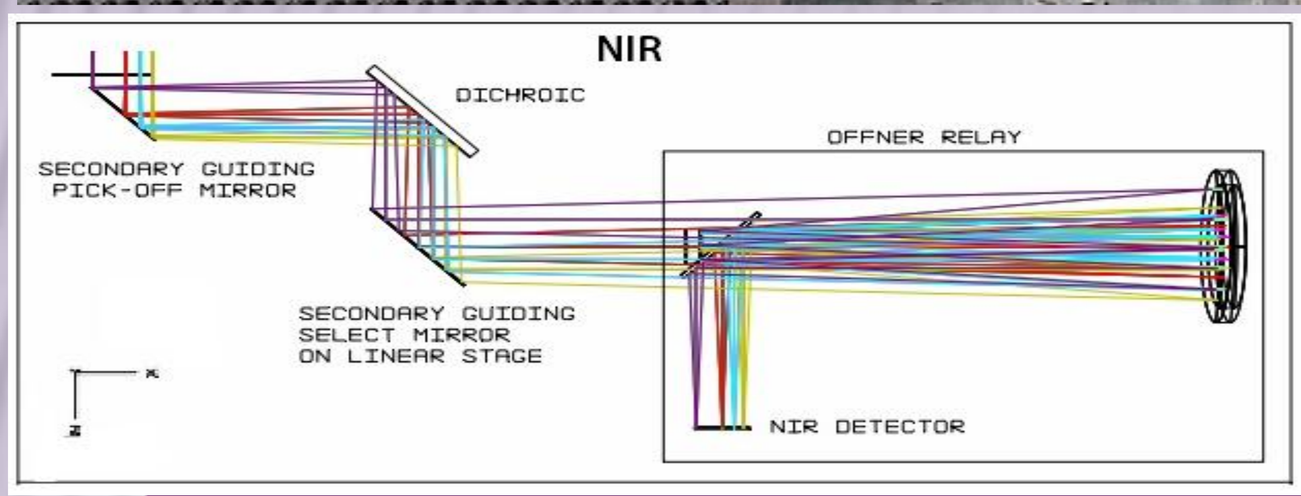
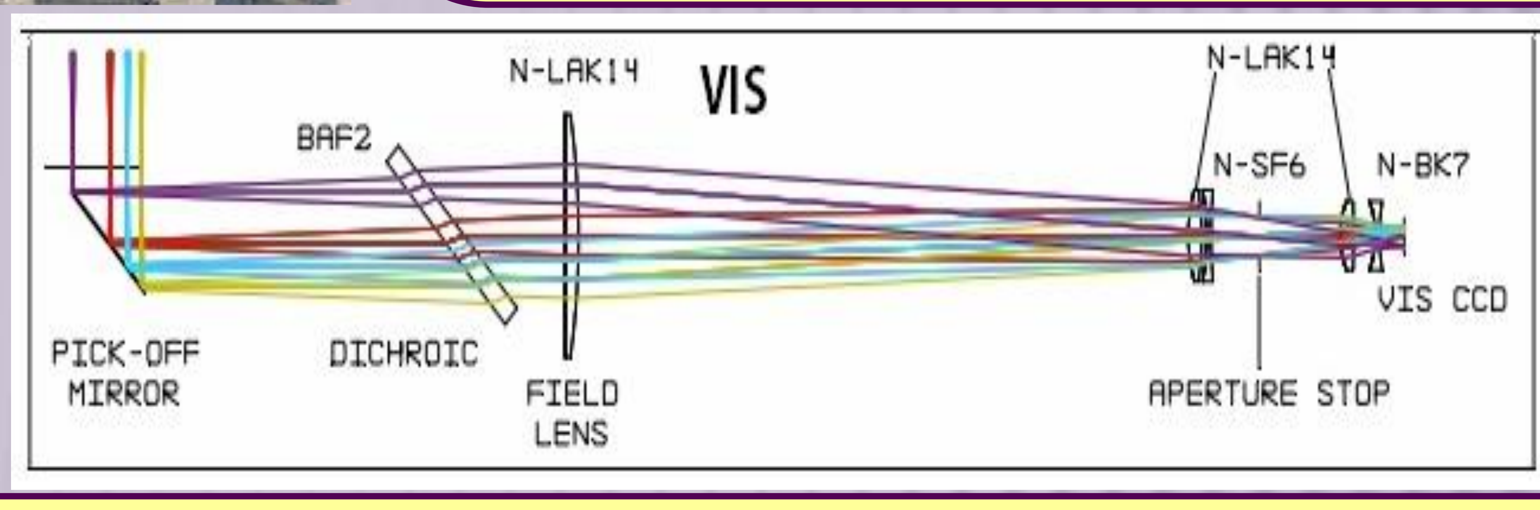
ABSTRACT: HARMONI is a first light optical-infrared integral field spectrograph (IFS) for the European Extremely Large Telescope (E-ELT). Its spectral range spans from 0,47 to 2,45 microns. Secondary guiding provides compensation for any differential image motion between the telescope (or AO) wavefront sensor and the instrument focal plane. Required accuracy changes substantially depending on the telescope PSF, so the secondary guiding implements both visible and near infrared sensing (NIR is more sensitive when the PSF is sharper). In order to constrain its design, we have started a study to understand the dependency of the main variables involved on its performance. Here we present some preliminary results which will help, for instance, to define the size of the field of view, pixelation, and working frequency (~1Hz) for this system.

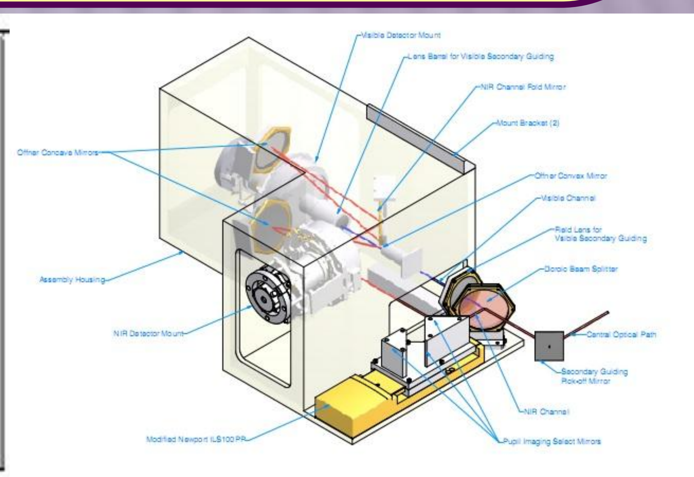
INTRODUCTION: *Secondary guiding (SG) provides an image position sensor, compensating for vibrations and diferential flexure. Science-FoV is offset w.r.t. the telescope optical axis, allowing part of the light to be directed to SG sensor. Mis-alignments are measured at ~1Hz by measuring the centroid of natural stars or galaxies, and outputs are used for telescope pointing.*
SG has to be fast enough to work with finest pixel scales, which requires to be computationally cheap and fast optics.

OPTOMECHANICAL DESIGN OF THE SG: VIS + NIR

HARMONI covers a wavelength range from 0.47 to 2.45 um. Then a two-arm design of the SG comes handy, with a dichroic that splits the beam on its NIR and visible parts. NIR path reaches a HAWAII-2RG sensor and the expected scale is about 6 m.a.s./ pixel whereas the visible beam reaches a cheaper CCD detector, and the scale will be about 85 m.a.s. / pixel. Scales of 5 m.a.s. and 100 m.a.s. were used in simulations, in order to match scales of the Exposure Time Calculator. Figures below show optical designs and the CAD model of the SG made at University of Oxford at phase-A.







METHODS AND RESULTS

Performance depends on a high number of variables such magnitude, star type, airmass, PSF, integration time… Expected FWHMs are 300 m.a.s. for GLAO and 8 m.a.s. for LTAO. Then we try to estimate the limiting point-source magnitude that allows a subpixel precision in centroid estimation using three different methods. Varying parameters are pixel scale, reference area, magnitude and AO flavour. Results can be summarized as:

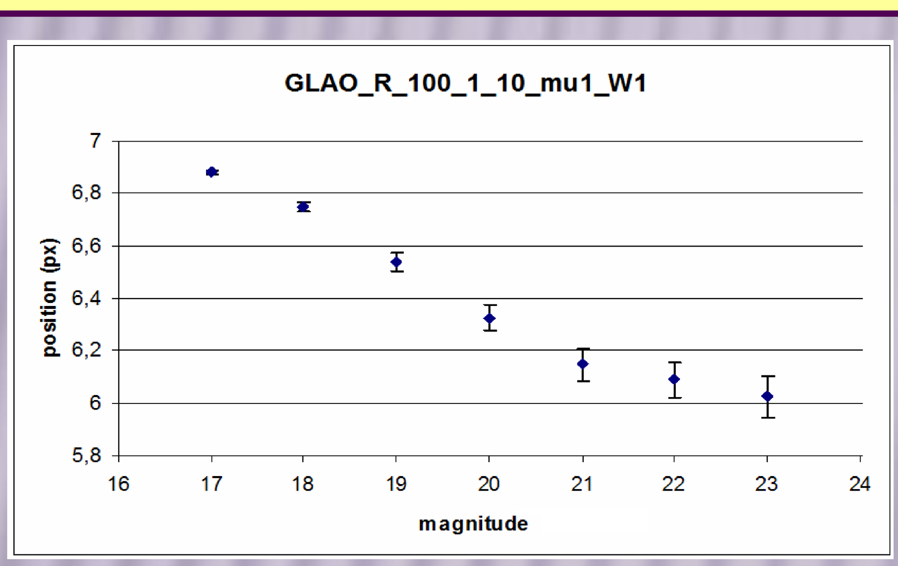
Weighted Centroid estimates the "signal + noise" centroid over 100 trials for each magnitude, by the weighted gravity center of the signal inside the reference area. When the source is not in the central pixel of the reference area, this method shifts the centroid to the central pixel (the central pixel is the expected centroid for a random signal). Systematic errors are much higher than dispersion produced by increasing magnitude. Departures greater than 0,5 pixels arise from 19th magnitude onwards for GLAO and 17th for LTAO, although it might be partially corrected by weighting pixel values.

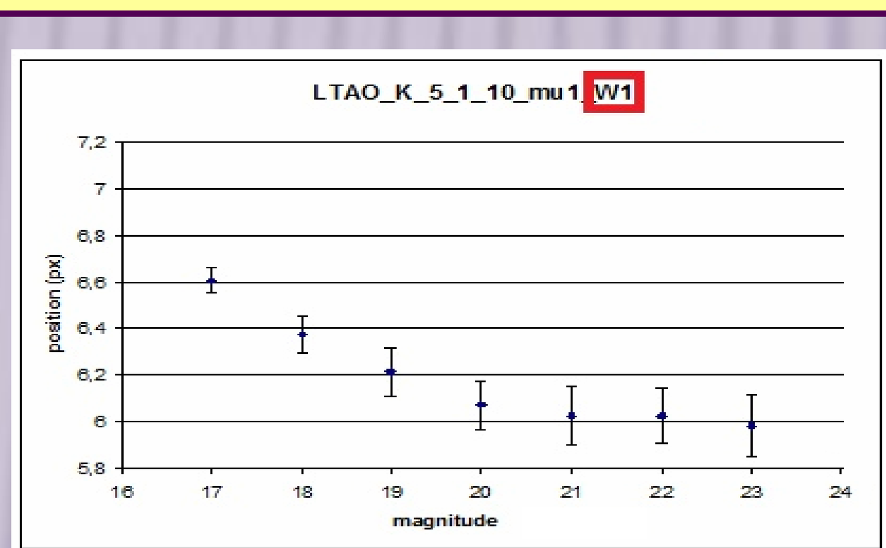
2D-gaussian fitting is not affected by the systematic error described above, but is limited by noise. Depends critically on the initial guess for σ, and then on AO-mode expected performance. Half-pixel precision is achieved up to magnitude 21 (see table below).

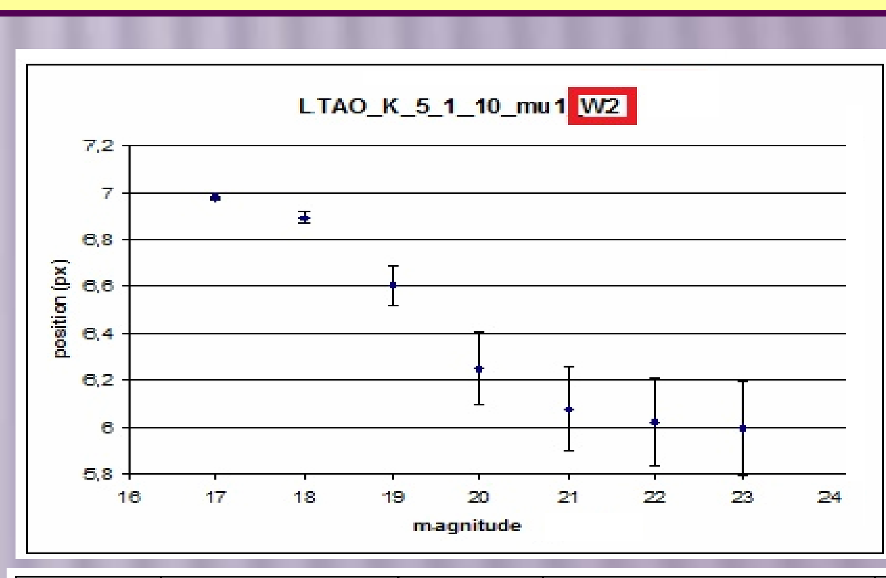
Cross-correlation methods were applied between two shifted images and 100 trials were ran for each configuration. Displacements are detected at magnitude 21 for LTAO and magnitude 22 for GLAO (see table below).

Default values are: star type: A0V ; Photon-electron efficiency = 0,5 (ETC) ; Airmass = 1 ; Integration time = 1s

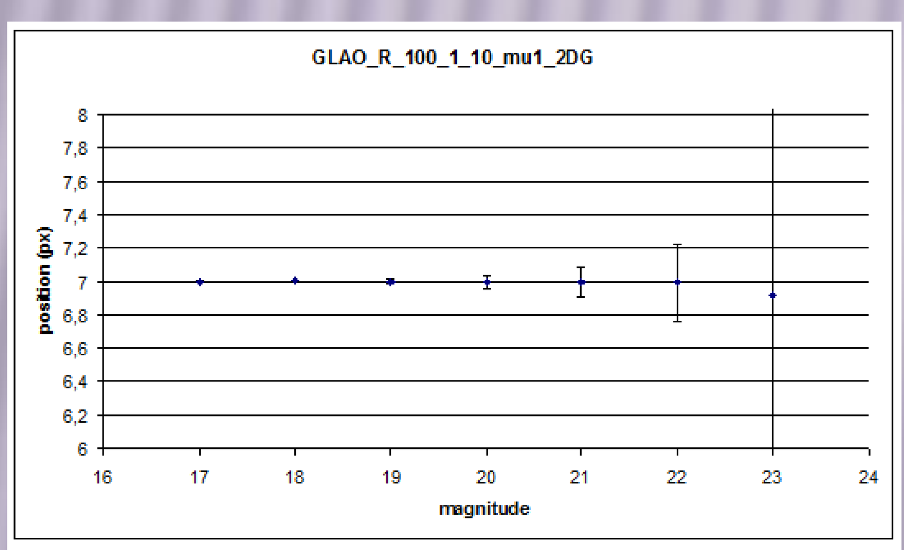
Weighted centroid

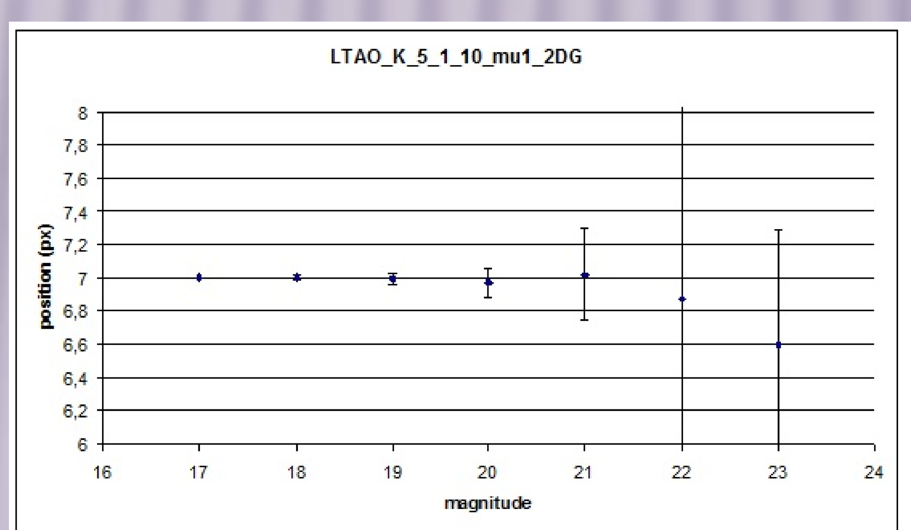






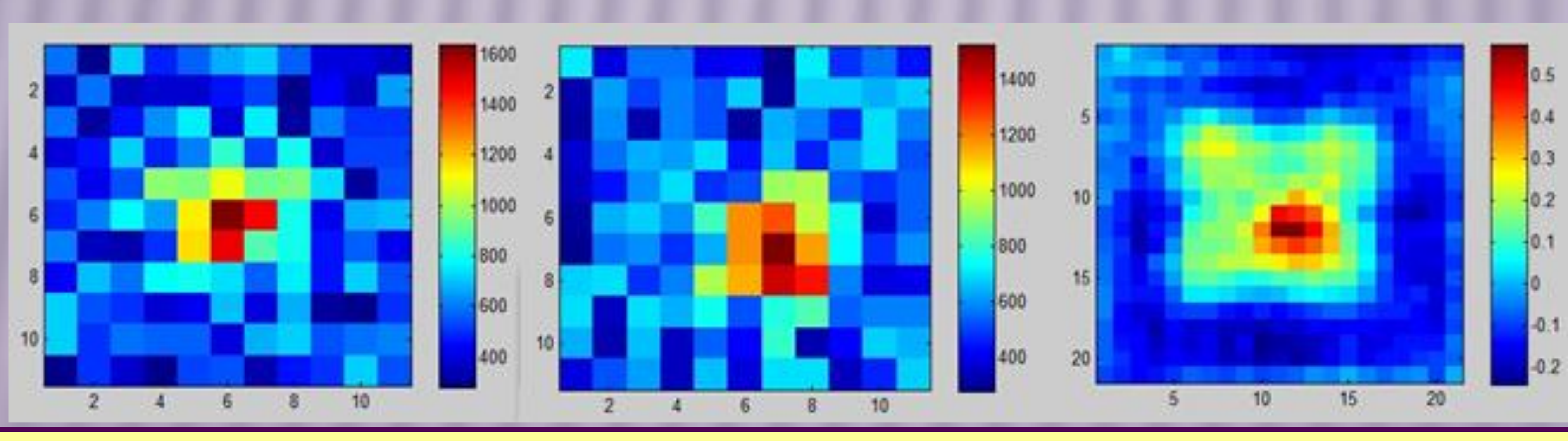
2D-Gauss fit





AO	magnitude	band	Px scale (mas/px)	Nref (NxN)	Radj^2
GLAO	20	R	*50*	*10*	0.89
GLAO	20.5	R	"	"	**0.78**
GLAO	21	R	"	"	0.60
GLAO	21.5	R	"	"	X
GLAO	20	R	*100*	*10*	0.95
GLAO	20.5	R	"	"	0.86
GLAO	21	R	"	"	**0.74**
GLAO	21.5	R	"	"	0.51
LTAO	19.5	K	*5*	*10*	0.73
LTAO	20	K	"	"	0.55
LTAO	20.5	K	"	"	0.38
LTAO	20	K	*5*	*5*	0.96
LTAO	20.5	K	"	"	0.89
LTAO	21	K	"	"	**0.72**
LTAO	21.5	K	"	"	X

Cross-correlation



AO	magnitude	band	Px scale (mas/px)	Nref (NxN)	% detections
GLAO	20.5	R	*50*	*10*	**90**
GLAO	21	R	"	"	45
GLAO	20.5	R	*100*	*10*	99
GLAO	21	R	"	"	**92**
GLAO	21.5	R	"	"	48
GLAO	21.5	R	*100*	*5*	98
GLAO	22	R	"	"	**85**
LTAO	20	K	*5*	*10*	**99**
LTAO	20.5	K	"	"	45
LTAO	21	K	*5*	*5*	**98**
LTAO	21.5	K	"	"	50

OUTLOOK

The SG system is complex and for its design one has to perform a tradeoff between fast optics, FOV and frequency, which is directly linked to integration time and image processing. The lower the magnitude we need for the guiding, the larger the FOV needed to find such bright source. Future work depends critically on final preoptics design, which will freeze volume budgets for the optical and the whole subsystem. Pixel scales will depend also on the expected AO performance, which is still under study. Centroid estimation algorithms will also be optimized.

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