to visiting astronomers as of October this year. Preliminary limiting magnitudes (1 σ in 30 minutes integration time through a 7.″5 diameter diaphragm) are given in the table.

These limits are consistent with those achieved at the 3.6-m telescope, after scaling for the difference in telescope diameters, except at $\lambda \geq 10\ \mu m$ where the only measurements possible at the 2.2-m were affected by thin cloud.

Band	J	H	K	L	M	N	Q
Centre wavelength (μm)	1.25	1.65	2.2	3.8	4.8	10.3	18.6
Limiting magnitude	19.6	19.3	18.4	13.8	11.0	6.8	3.3

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Progress Report on DISCO: A Project for Image Stabilization at the 2.2-m Telescope

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1. Introduction

It is well known that the resolution of earth-bound large telescopes is normally limited by the atmosphere, and not by diffraction. The astronomical image formed by a large telescope consists of a number of speckles, caused by the atmospheric refractive index variations. Every speckle is defined by a coherence zone over the pupil of size r_o, also known as the seeing parameter. These coherence zones cause a blurring of the image and also a motion of the centre of gravity of all the speckles. In addition, image motion can have local origins (dome seeing, tracking and guiding errors). As a result, short-time exposures, where the motion is frozen, may have a higher resolution than long exposures.

Until recently, little was known experimentally about the temporal behaviour of image motion. A theoretical model, originally proposed by Kolmogorov, describes the decrease of the power spectrum of image motion with temporal frequency[1]. Recently, experimental data on power spectra of image motion have been published in the context of site testing[2] and speckle interferometry[3]. In cases of good seeing, which we define somewhat arbitrarily as $r_o \geq 15 cm \Rightarrow$ FWHM = 0.7″, the frequency dependence of the power spectra was indeed observed[2] (if the seeing is bad, the number of speckles is too large and image motion is averaged out). A typical time constant of the image motion is estimated from these data as 200 msec. Under such conditions, an imaging facility which corrects the image motion may improve the resolution of long integrations. Such a device is presently under construction at ESO for the 2.2-m telescope, and it is called DISCO, acronym for Direct Image Stabilized Camera Option. A similar stabilizer has been operating at the 2.2-m telescope of the University of Hawaii for some time[4]. The main task of DISCO will be to enable the observer in case of good seeing to switch within few minutes from "normal" exposures at the Cassegrain focus of the telescope f/8, (image scale of 0.35″/pixel for a RCA CCD) to stabilized exposures with 0.14″/pixel. The possibility of a quick changeover in the observation mode is considered an advantage, since periods of good seeing might be limited to a fraction of the night and in any case

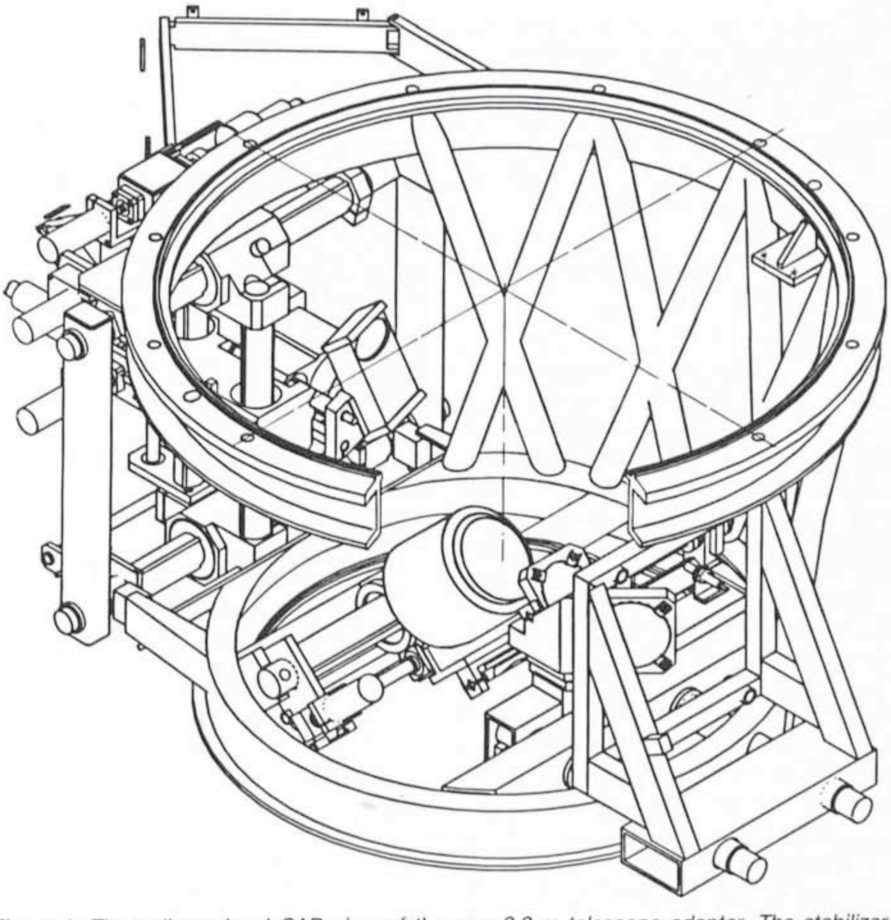

Figure 1: *Three-dimensional CAD view of the new 2.2-m telescope adapter. The stabilizer mirror is visible in the centre on its linear translation stage.*

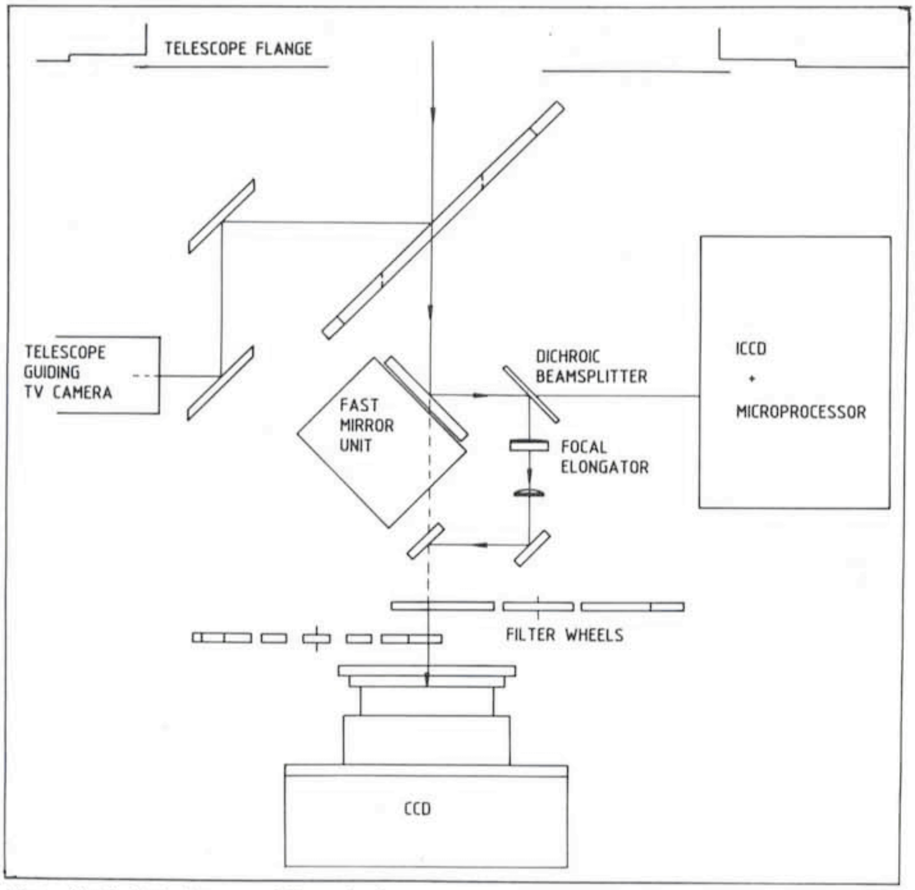

Figure 2: *Optical diagram of the adapter.*

the high resolution mode might be required for a part of the observing programme only. Finally, image stabilization is a first natural step towards a fully adaptive optics system and one may expect to gather valuable experience and useful data on the image quality on La Silla from DISCO observations.

2. The Design and Operating Concept of DISCO

To realize DISCO, a new lightweighted adapter for the 2.2-m telescope was designed and is now under construction (Fig. 1). The adapter will be used with the direct image CCD camera and with spectrographs. It includes an offset autoguider based on a SIT camera. The offset guider XYZ motion units are using the ESO standard DC motors; this makes it possible to position the guide probe accurately ($\leq 0.3''$) within the acquisition field which may be a help for automatical acquisition or remote control. The field for guiding is $30' \times 30'$, comparable to the present camera. The new adapter has been prepared to include in a later stage spectrographic calibration units, and Risley prisms (in the focal elongator). The optical diagram is drawn schematically in Figure 2. The conventional imaging mode is the f/8 focus. In this case the stabilizer mirror is not in the beam path. If the seeing is good ($r_0 \geq 10-15$ cm), the observer may expect an additional advantage in the angular resolution by switching to the stabilized mode. To this aim the fast mirror unit (see Fig. 3) is remotely inserted into the main beam (under 45°). It consists of a high-quality (surface flat $\leq \lambda/10$) mirror which can be repositioned within 1 msec around 2 axes; its dynamic range is 8×10^{-4}rad; this covers a field of 4.5″ on the sky. From the mirror the beam is reflected onto a dichroic beamsplitter (also under 45°). The blue beam (light $\leq$ 560 nm) is imaged onto an ICCD camera, and is used for the acquisition of the centre of gravity. The red part (light $\geq$ 580 nm) is reflected from the beamsplitter, passes through a focal elongator and forms (via 2 additional 45° mirrors) an image onto the CCD camera: this is available as stabilized image.

The signals to drive the mirror are calculated every 20 msec by a fast microprocessor. This is done as follows: at the beginning of a stabilized run the observer selects a suitable guide star on the ICCD camera by placing a subframe of 16×16 pixels around it (the camera covers a field of $1.5' \times 1'$, corresponding well with the isoplanatic patch). Then this subfield is digitized after integration every 20 msec; in the present configuration the system is limited to TV rates by the camera electronics. For astronomical applications this means a limiting magnitude for the guide star $m_B = 13$ within $1' \times 1'$ from the object. Initially

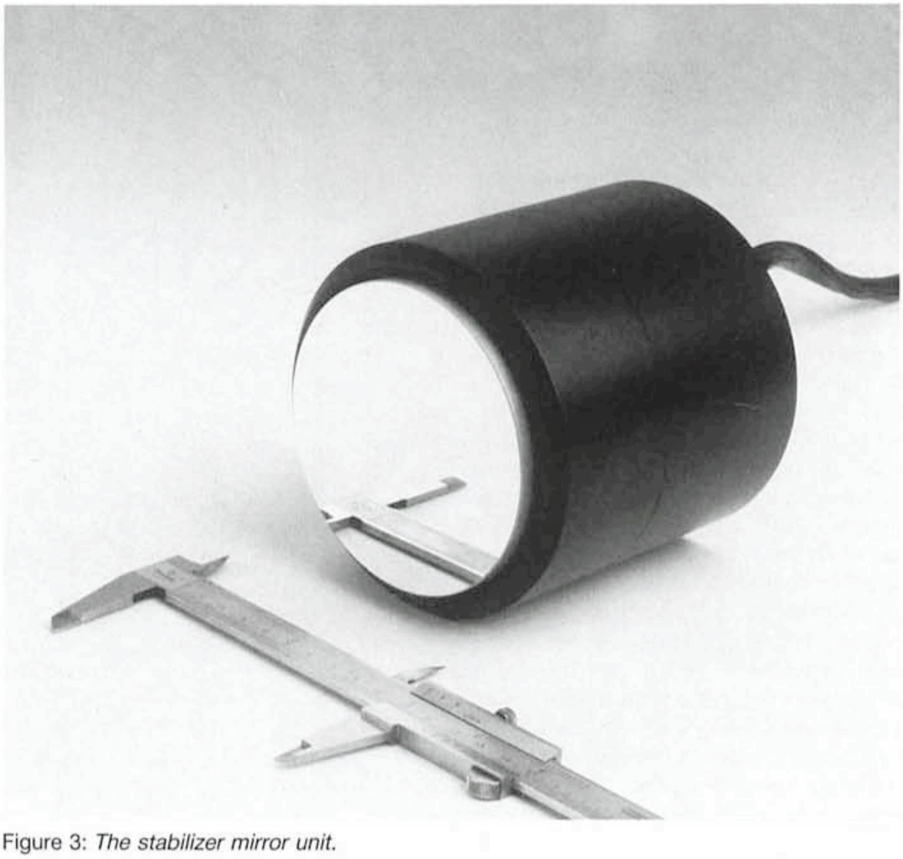

Figure 3: *The stabilizer mirror unit.*

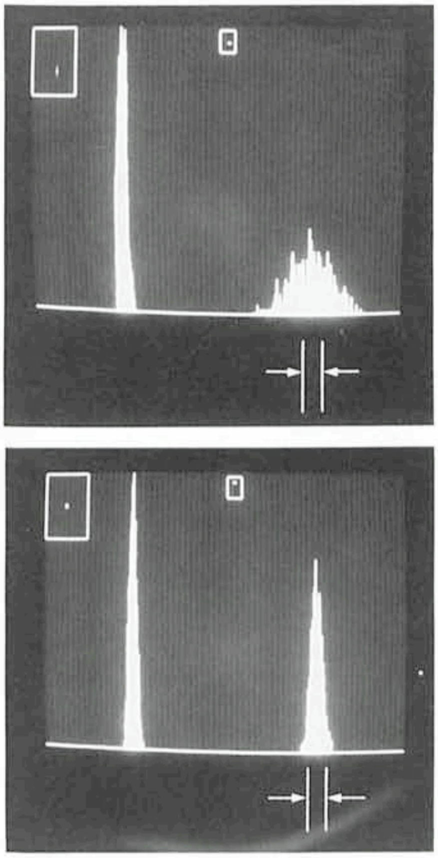

Figure 4: *non-stabilized (upper) and stabilized (lower) runs with the fast loop. The arrows below the* y-histograms indicate a width of 1/2 pixel.

the imaging in stabilized mode will be possible only at wavelengths ≥ 580 nm. A second dichroic reflecting the blue light will be ordered soon; then also wavelengths ≤ 580 nm can be stabilized, although one has to be aware that the seeing parameter scales as $r_o \propto \lambda^{1.2}$, therefore the stabilization is more effective for longer wavelengths.

The digitalization and the display of image information is performed by a fast video digitizing VME card. The centre of gravity within the subframe and the new mirror coordinates are calculated with a 68010 microprocessor (also VME based). The entire operation: reading out of the subframe, digitalization, calculation of new coordinates and repositioning of the mirror takes 4 msec for a 16 × 16 subframe or 2 msec for an 8 × 8 subframe. The total cycle time is then 24 msec; two samples (i.e. 50 msec) are needed to acquire a frame (Shannon sampling theorem). Therefore the stabilization starts to be effective if the atmospheric coherence time is longer than 50 msec. It was mentioned earlier that good seeing has a typical time scale for image motion of 200 msec; therefore under such conditions DISCO is expected to improve the resolution.

3. Present Status of the Project, Results from the First Laboratory Tests

The fast moving mirror was delivered to ESO in September 1986; in dynamic tests in the optical lab it was verified that the surface remains flat during the fast motion. The microprocessor was acquired; all the software was written in assembler language to obtain maximum speed in calculations. In the mean time the structure and the mechanical functions of the adapter are being manufactured by external European firms, and these will be delivered in the summer of 1987.

In the laboratory, first tests of the DISCO fast loop have been made. Atmospheric image motion was simulated using a galvanometer scanner mirror, which was excited with electrical noise having a power spectrum similar as in [2,3]. A pinhole source was imaged with this mirror and the stabilizing mirror onto a CCD camera. In this way, apparent image motion along one axis was simulated. The results of the stabilization are shown in Figure 4: it contains photographs of the video display of the VME control system. The upper photograph is the non-stabilized case: in the upper right box is the momentary ("real-time") image of the reference star in the selected subframe (in this case 16 × 16). The upper left box shows a zoomed display of the centres of gravity, as calculated by the microprocessor. The lower curves are histograms of the centres of gravity in *x* and *y* direction. Comparing the upper and the lower picture, a significant improvement in the *y*-histogram is noticed. The microprocessor also gives the number of centres of gravity, which would be contained in a circle with a preset radius ("energy concentration"). Taking a radius of 1/4 pixel the stabilized image has 570 out of 1,023 samples in the circle, the non-stabilized has 190 out of 1,023 samples. We notice that these simulations were made with high S/N ratio, and on one axis. Under such conditions the centre of gravity can be calculated with an accuracy of 1/10 of a pixel. Further tests to simulate different observing conditions at the telescope will be carried out in the next months.

It is planned to have a first test of the instrument at the telescope towards the end of 1987. Provided that the seeing conditions will be appropriate, we hope to demonstrate that DISCO can be a valuable tool for those aiming at high-resolution imaging. The full implementation of the facility is expected to take place during 1988.

References

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MIDAS Memo

ESO Image Processing Group

1. Application Developments

The Inventory package for detection and classification of objects has been significantly improved by Dr. A. Kruszewski. He will in the coming month integrate these modifications in MIDAS.

In order to provide a high-quality crowded field photometry system, the ROMAFOT, package (Buonanno, R., Buscema, G., Corsi, C.E., Ferraro, I., Iannicola, G.: 1983, *Astron. Astrophys.* **126,** 278) has been adopted by MIDAS as the standard system for this purpose. The implementation of this package is done in close collaboration with Dr. R. Buonanno and is expected to be terminated during the summer. General MIDAS tables for exchange of information between the different packages are being designed to make combined use easy.

The Time Series Analysis package for unequally spaced data developed by the ST/ECF was fully implemented and will be released in the 87 JUL 15 release of MIDAS. It includes different methods for calculation of Power spectra and periodicity determination of data in MIDAS tables.

As a result of the collaboration with the Image Processing Group in Trieste, two new commands for interactive analysis of spectra developed by F. Pasian and G. Sedmak, are under testing. The commands, being the nucleus for future interactive developments, will be available in the 87 JUL 15 release.