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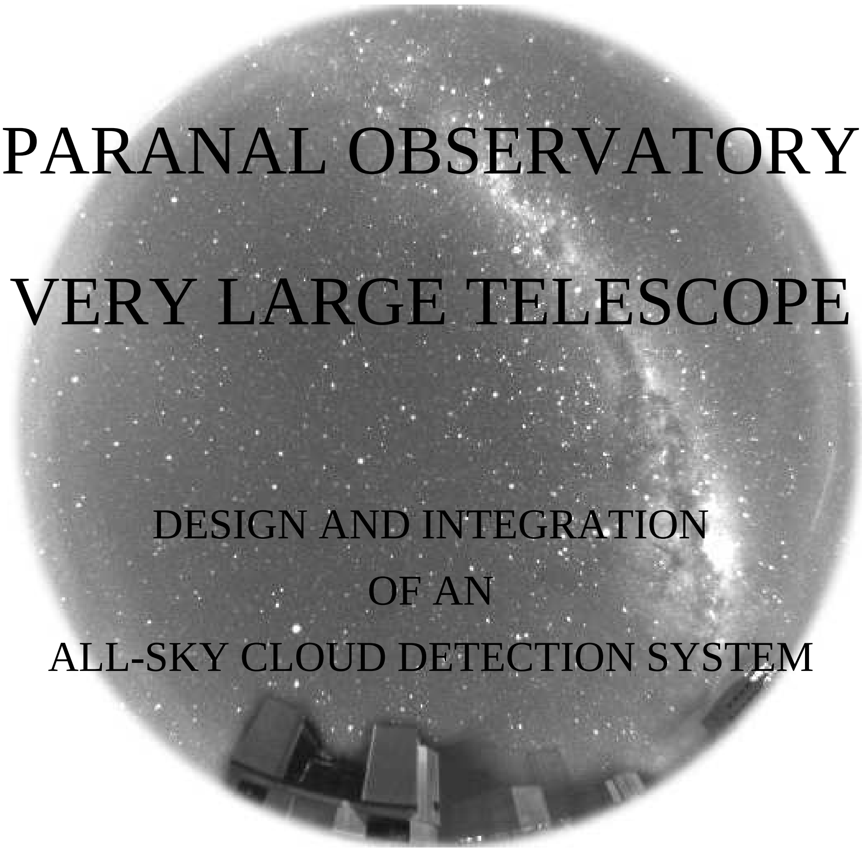

PARANAL OBSERVATORY

VERY LARGE TELESCOPE

DESIGN AND INTEGRATION
OF AN
ALL-SKY CLOUD DETECTION SYSTEM

Doc. No.: VLT-XXX-YYY-00000-0000

Issue: 1

Date: 27/08/2002

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Change Record

Revision	**Date**	**Section-Paragraph**	**Remarks**
Issue1	08/08/2002	all	

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1 Abstract

DESIGN AND INTEGRATION OF AN ALL-SKY IMAGING SYSTEM

This report describes my work from March to August 2002 at ESO (European Southern Observatory) at Cerro Paranal (Chile). The purpose of the work was to design and build a camera to perform an evaluation of the sky cloud cover over the Observatory. The successive tasks have consisted in searching the best camera and optics combination, programming the control software, building the mechanical system and integrating it in the Observatory system.

CONCEPTION ET INTEGRATION D'UN SYSTEME D'IMAGERIE CIEL ENTIER

Ce rapport de stage présente mon travail réalisé de Mars à Août 2002 au sein de l'ESO (European Southern Observatory) à l'Observatoire du Cerro Paranal (Chili). Le but du travail était de mettre au point et concevoir une caméra permettant l'évaluation des nébulosités nocturne au dessus de l'Observatoire. Les tâches successives ont consisté à faire une recherche de la meilleure combinaison caméra et optique, à mettre au point le logiciel de pilotage du système, à réaliser l'assemblage mécanique et à intégrer l'ensemble dans le système de l'Observatoire.

2 Introduction

2.1 Description

I've been working for 6 month in the Engineering Department (Instrumentation Group) of Paranal Observatory in Chile. The work consisted in developing a new system to permit the astronomers to evaluate the quality of the night sky and its cloudiness. This should be a small instrument integrated in the VLT system. It had to be sufficiently simple to be entirely designed and in operation within the end of my training.

J'ai travaillé durant 6 mois au sein du Département d'Ingénierie (Groupe Instrumentation) de l'observatoire du Paranal au Chili. Ce travail a consisté à développer un nouveau système afin de permettre aux astronomes d'évaluer la qualité du ciel nocturne et la couverture nuageuse. Le système devrait être suffisamment simple, intégré a terme au système du VLT et fonctionnel a la fin de mon stage.

2.2 ESO and Paranal Observatory

The European Southern Observatory is an organisation of ten member states (Belgium, Denmark, France, Germany, Italy, Netherlands, Portugal, Sweden, Switzerland and more recently United-Kingdom) created in the 60's in order to develop the astronomical research in the Southern hemisphere.

Chile has been chosen for the quality of its sites and for its climate. The first observatory has been built in La Silla, close to La Serena about 30 years ago. More recently, the project of the VLT (Very Large Telescope) needed a site: the selected location was on the North of Chile, in the Atacama desert. The observatory was build in the 90's and in 2002 the four 8.2 meters telescopes are fully functional.

The next step is the exploitation of the interferometer system (VLTI) which combines the beams from several telescopes in order to improve the angular resolution of the observation.

Figure 1 - Paranal Observatory from the Basecamp

3 Purpose of the instrument

3.1 Purpose

During my training, I've been in charge of the development of an all-sky imaging system.

The purpose of this instrument is to help the astronomers to evaluate more easily the quality of the sky, its cloudiness and to complete the weather monitoring system in place.

From the beginning, the quality of the night sky at Paranal has been evaluated visually by a telescope operator, every hour. In addition, a "DIMM telescope" gives an evaluation of the seeing and of the extinction along its line of sight, but can't make an analysis of the clouds extension over the whole sky. The idea was to provide a system that would give an image of the current sky, with the best possible angular coverage, and at a fast rate (compatible with cloudiness evolutions, i.e. 1 image every 1 or 2 minutes). The camera would permit to detect thin clouds, and possibly other phenomena (shooting stars, satellites, planes and contrails, parasite lights, etc...).

Such equipment is used in other observatories. For example, the ConCam project (Continuous Camera), run by Robert Nemiroff, is installed in six observatories worldwide and provides updated images on the Internet. Other observatories such as the Tololo, in Chile, have similar projects.

The system had to be fast and easy to develop and to build. This requirement oriented the search to "commercial" equipments.

In the course of the work, an acronym was chosen to designate more easily the entire system, and I'll use it for the rest of this report: MASCOT (Mini All-Sky Cloud Observation Tool).

3.2 Overview of cloud detection methods

We have two main methods to detect clouds: using infra-red detector of visible detector, keeping in mind that the contrast of the image will be provided by:

- the thermal emission of the clouds, at 8-12 microns (IR)
- the extinction of airglow, at 1-2 microns (IR)
- the extinction of starlight & airglow, at 0.4-1 microns (Visible)

3.2.1 IR detection

Clouds can be easily detected in Infra-red light. The main advantages is that the clouds are detected equally well in starlight, moonlight and daylight.

However, the disadvantages are multiple:

- the cold clouds (high altitude) are harder to detect;
- the detector/system is expensive;
- the all-sky coverage is a problem;
- the light pollution can't be monitored (only clouds and IR light);

Some solutions can be found, such as using a custom silicon fish-eye (very expensive) or using a hemispherical gold reflector (but problems of emissivity of the mirror).

For example, Apache Point Observatory has such an IR detector, using a scanning system with two mirrors that cover the entire sky (using slow scan motor). The detector is an HgCdTe tuned for 10-12 microns and cooled by nitrogen. Not only the system is complex but also it's very expensive! (100,000US$)

3.2.2 Visible detection

Basically, the visible detection is done with CCD-based detectors. Compared to IR detection, the advantages are the following:

- much reduced price for the detector (about 10 times cheaper) and bigger size and resolution;
- greater spatial resolution, no moving parts (compared to IR-scan solution);
- light pollution monitoring is possible;
- airglow monitoring is possible;
- standard wide-angle optics can be used;
- N2 cooling is not necessary; easier to use;

The CCD Visible detection is mainly based on the extinction of background sky by the clouds (dark clouds over bright background starlight). When the moon is visible, the clouds are illuminated and appear brighter over the dark sky. This qualitative result has been preliminary confirmed by Pedro Mardones during and experiment with an SBig CCD camera.

4 Specifications

Due to the remarks above and the differences between IR and VIS detection, the basic choice was oriented to a Visible detection system using a CCD sensor.

The high level constrains are:

- ability to work in outdoor conditions in Paranal all year long (cold/hot, snow/rain);
- images available in all lunar phases;
- ability to run automatically (as few as possible human intervention);
- all-sky view, if possible 180° (horizon-to-horizon hemispheric view);
- user interface allowing the control of the camera and visualization of the images;

In addition, the system had to be easy and fast to develop and build, at a reasonable cost (few thousand Euros).

From the user point of view, MASCOT has to be an interface installed in the Control Room. The user would check for clouds playing a 'movie' made of images taken by MASCOT and browsing the images.

All the parameters necessary to take the images, such as repetition rate, exposure time, and other parameters, will be in configuration files transparent to the user.

One must discuss the SW design, as it could be useful and safer to separate the automatic control of the camera and the visualization of the images.

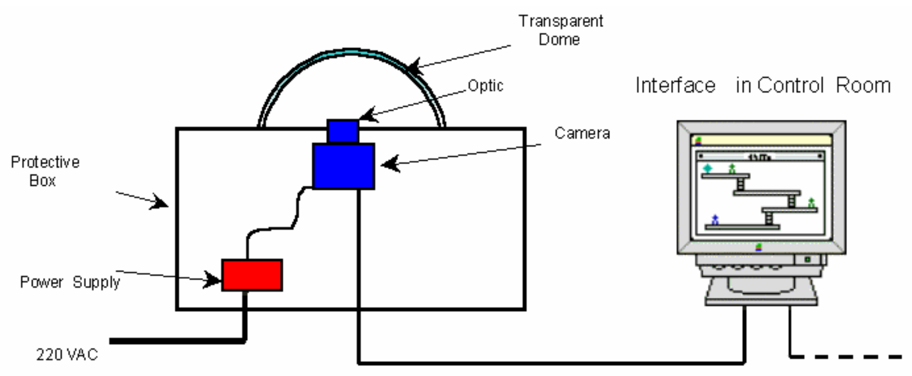


Figure 2 – Schematic view of the system

Concerning the software, the purpose is to have it the most integrated to the VLT system: this means that we will need to have a program running from any machine of the Control Room.

At ESO, every new software component must be tested and declared as "VLT Compliant": that mean that every component is declared in a Module that follows strict rules, stocked in Garching, and every modification is made by downloading the code from Garching. The organisation of a module is exposed in definition documents and respects programming standards.

This first requirement reject Windows-based solutions for security purposes. The remaining valid solutions remain the X-based solutions: whether to develop a soft using existing parts of the VLT software (quite a big task!), whether to find a control software running under Linux. No Linux PC had previously been connected inside the VLT-network, nevertheless this solution has been tested and approved recently in Garching, so it's possible to integrate a Linux PC in the VLT Network.

5 Technical choice

Before I came to Paranal, a preliminary work had been done by Pedro Mardones (Instr. Dpt.) using a commercial CCD camera and a wide angle optical setting. He had made images of the night sky with the clouds easily visible. That test showed that the detection with a CCD sensor was possible. It also showed that the clouds are much more detectable if the user looks at a movie constituted by the successive frames.

I investigated over a wide range of camera, from video cameras to “science” CCD cameras or to general public digital cameras.

I also investigated the different optics available, as it was preferable to choose an off-the-shelf wide field lens rather than to build a focal adapter to the camera.

Simultaneously, I investigated the possible software platforms for the control of the cameras under investigation.

As a conclusion, different combinations (camera + optics + software) were proposed and one was finally selected. In the following paragraphs, I’ll summarize the results of the investigation.

5.1 Review of different solutions

This section reviews the different solutions that were proposed.

I first oriented my search into a study of existing similar devices, trying to analyze strong and weak points. I then made a review of all CCD based cameras and all wide-field optical system. The software solution often came with the cameras, as it is usually very specific to each equipment.

5.1.1 Camera Systems

5.1.1.1 Commercial digital cameras

In this paragraph, are listed the different types of commercial digital cameras. I decided to include in this category the following products:

- photographic digital cameras (Nikon, Olympus,…) that “flood” the public market;
- video cameras, usually used for security purposes, or in biological applications;
- webcam cameras, used mainly for videoconferencing, but also in some specific applications;

These cameras are generally used for short exposures (from 1/2000 to some seconds) or video stream (60fps or less, sometimes, frame capture is possible). They are generally not cooled, and also very cheap. The principal disadvantage of these cameras is their high dark signal for long exposures (more than several seconds), as they are not cooled. This would require to subtract the dark frame from the raw image, but the thermal noise remains very high. This kind of camera is optimized for daylight and quite short exposures, and can’t make good photos of faint stars. In addition, it seems difficult to control them from a computer: some tools exist however in some cases (generally developed by amateurs).

Their advantage would be their low cost (due to the massive production) and the existing fisheye optics of some models.

5.1.1.1.1 Photographic digital cameras

Several models, for example Nikon Coolpix 950 and 990 (1/2”CCD sensor, 1.13” CCD sensor); ~400 US$. Fisheye optics: Nikon fisheye lens with 183° coverage, ~220 Euros.

Non-cooled cameras: high thermal noise - for a 60sec exposure on CP990: moderate noise at 10°C and below; image not usable at 15° and above (Paranal average night temperature is ~11°C).

Software: cPix: free camera control software, ability to take shots, import, etc... script command language available.

That kind of system would be particularly interesting because of the high resolution (>1Mpixel) and the existence of a full compatible fisheye lens. Commercial digital cameras are often used to make auroras monitoring, however, the thermal noise is their weak point.

5.1.1.1.2 Video cameras

Many models; generally not cooled; video output requires a frame grabber card (digitization of the video signal) and generally the need to make an addition of the exposures in case of low light (price varies from 3000Euros to 5000Euros... or more!); most of the sensitive cameras are optimized for high-speed applications (high frame rate), unlike our application. Some cameras are cooled by Peltier modules.

Sensitivity from >1 to 0.001 lux (Watek LCL811K) or less. Trademarks: Pulnix, Watek,...

5.1.1.1.3 Webcam-based camera

Many models, generally 640x480 CCD ships (1/3" or 1/4"), non-cooled cameras, and necessity to adapt the adequate optics (see 190° Omnitech Robotics fisheye lens).

Software: many solutions available; possibility of adding exposures; also run by Prism and AudeLA (see later).

Example of models:

- Philips VestaPro PCVC680K: color CCD sensor 1/4"; 640x480 pix (5.6um pix); widely used in amateur astronomy: good support, modifications and docs... price < 40-50 US$

- Philips Toucam Pro PCVC740K: color CCD sensor 640x480; sensitivity<1 lux ; price < 100 US$

A cooling Peltier module is needed to decrease the thermal signal and the quality of the image is generally low.

5.1.1.2 CCD Astronomy cameras

In this paragraph, we list different types of cameras usually used by amateur astronomers or scientific applications. These cameras are cooled, with CCD sensors from 1/3" to 1/2" or more. They are optimized to allow several minutes exposures at low noise. Commercial CCD cameras (SBig, Starlight) range from about 1500Euros to several thousands Euros. In order to decrease the costs, advanced amateur astronomers have developed cooled CCD cameras available in kits (less than 800Euros) or ready-to-use (less than 1500Euros), like the models Audine (Fr) and Genesis (US).

5.1.1.2.1 SBig astronomy cameras

Several models, for example:

- ST-237A, TI TC-237 CCD sensor 657x495, 4.7x3.6mm; ~1300US$;

- ST5C, ST6B (~350x240pix);

- ST7E, Kodak Kaf401E CCD sensor 765x510, 6.9x4.6mm; ~2700US$;

Necessity to adapt an optic (i.e. fish-eye adapted to the CCD size: 6.9x4.6mm); Cooled camera (peltier)

Software:

- Prism: ~60US$, ability to run scripts / image processing (only ST5, 7, 8, 9)
- SBig dedicated software: image acquisition/processing

5.1.1.2.2 Starlight XPress MX5-C

Sensor: Sony ICX055BK color CCD, 500x290pix, (9.8x12.6umpix) 4.9x3.6mm

Cooled camera (-30° to ambient), 12 bit digitization, anti-blooming; ~1200US$

Can be driven with AudeLA software (recently) and Prism. Could be a good solution, but also needs to adapt the optics.

5.1.1.2.3 Audine astronomy CCD camera

Kodak KAF-401E CCD device: 765x510pix , 6.9mm x 4.6mm

Necessity to adapt an optics (i.e. fisheye adapted do the CCD active surface 6.9x4.6mm)

Cooled camera (Peltier), about -30° to ambient;

Available tested and complete (no shutter, but easy to interface an external one), ~1200 US$

Several software:

- AudeLa: free SW, ability to run scripts and adapt/build interface (TCL/Tk), image processing, ephemeris, …
- Prism: ~60US$, ability to run scripts / image processing

5.1.1.2.4 Genesis (US Audine) camera

Same general features as Audine as Genesis is a "clone" of Audine; the mechanics is however more hermetic and it has a shutter. Available assembled and tested, ~1500US$

Many types of software available, in particular AudeLa and Prism (see above: Audine)

5.1.2 Optical components

Edmund Scientific Optics:

Only 2 very-wide-field lenses available:

- Micro Video Lens: focal 2.1mm, f/d=2.5, FOV=120°; optimized for max CCD format of 1/3"; 53US$
- Varifocal Video Lenses: manual zoom: focal 1.8–3.6mm, f/d=1.6–Closed, FOV=144.2° to 79.4°, optimized for max CCD format of 1/3"; 195US$

Omnitech Robotics:

190° fisheye lens: max FOV=190°, nominal field diam=3.4mm, focal=1.24mm, f/d=2.8 (corresponding diameter about 0.45mm), optimized for 1/3" or 1/4" CCD ship; 250US$

Pelco:

Pelco 13VA1-3 1/3" zoom lens - 1.6-3.4mm, f/# = 1.4 to closed; on CS mount; corresponding diameter = 1.6/1.4 =1.14mm;

The data sheet mentions the following FOV on a 1/3" chip: horizontal FOV=180° (on 4.8mm), so it would fit almost entirely on a Kaf-401 (6.9x4.6mm); costs about US$180

Pentax/Asahi:

Zoom lens TS2V11E - 1.6-3.4mm for 1/3" sensors, f/# 1.4 to 64; Image size @ f/1.6 = 3.6mm for wide-angle; back focal distance = 8.07mm

Fujinon:

Same general features as Pelco or Pentax…(see models YV2.2X1.4A-SA2L, YV2.2X1.4A-2, DF1.4A-2, DF1.4A-SA2L)

Others…:

Use of a classic fish-eye lens for 35mm photographic cameras, with the use of a focal reducer to cover the CCD ship; Example: Peleng 8mm f3.5 Fisheye; (circular image fits on 24x36mm); 225US$

On some design, the focal reducer is a fiber optic taper directly bonded on the CCD sensor (reduction ratios. ~ 1:2 or 1:3). However, this kind of design is far to be optically perfect and the focal reducer would be complex to build and expensive.

Reflective optics:

This is a solution often used to obtain a high-angular coverage: it consists in a simple metallic convex mirror looking upwards. The camera is placed above the mirror, on a pod, with a standard lens. Due to its convex shape, the mirror reflects the whole sky and it's image is taken by the camera. However, the camera and the pod appears on the image (and obstruct part of the sky).

5.1.3 Software applications

For the commercial digital cameras, some control software are sold with the camera, or have been developed by amateurs. However, they usually don't have programming features, and an adaptation for our application would be problematic.

For the CCD astronomy cameras, two mains software seems to be recommended as they can control a wide range of cameras: Prism and AudeLA

Prism: is a Win32 application that can control several CCD cameras, and perform image processing, ephemeris calculation, astrometry, scripting. In addition it's written and maintained by C.Cavadore and B.Gaillard, who works at ESO. See http://www.astroccd.com/prism/.

AudeLA: This free software provides the ability not only to communicate directly with many cameras, but also to run scripts, to build a dedicated interface (widely configurable via Tcl/Tk language), to make celestial mechanic calculations, image processing, etc…

It can be run under Win95/98 or Linux and the scripting or interface programming is made using Tcl/Tk. In addition, it's an open system (sources available). See http://software.audela.free.fr/.

5.2 Final choice

The solutions using commercial digital cameras or video cameras were rapidly rejected because of their lack of sensitivity and their complexity despite a low cost.

Finally, the decision has been made to use a Genesis camera with a KAF-401LE sensor (antiblooming) and a fisheye lens Pelco 13VA1-3.

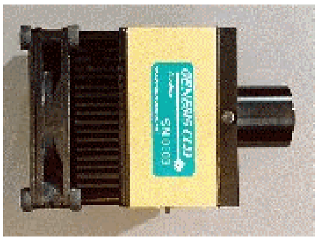


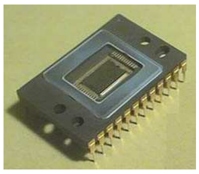
Figure 3- Genesis camera

The camera is a Genesis cooled camera with KAF-401LE (antiblooming) grade 2; according the the KAF datasheet, the antiblooming feature would be sufficient to manage with the moon luminosity and avoid saturation trails on the image.

The Genesis camera has been designed to be hermetic, by using hermetic connectors and o-rings. In addition, two little silica gel desiccant cartridges are placed in the camera. All the screws use also o-rings. It is also possible to lower the freezing risk by filling the camera with plastic foam (this technique has already been used by many camera owners and is particularly efficient). The critical point is the connection with the optics. It is necessary to adapt the camera cover in order to make it compatible with the optics (diameters and focal length). The mechanical interface is simple and can be done at Paranal.

5.2.1 The KAF401LE

First, here are some information about the KAF401LE sensor:



- 393 Kpixel area CCD
- 768 x 512 (9um) square pixels
- 6.91 x 4.6 photosensitive area
- Antiblooming technology -> fill factor 70%
- Low dark current: <7pA/cm² @ 25°C, equivalent to a nominal value of 15e-/pix/sec @ 25°C and about 0.1e-/pix/sec @-10°C

Its quantum efficiency is quite low (peak value 0.35 @ 600nm) due to the antiblooming technology. However, we considered that the antiblooming feature was more important to have a good interpretation of the image and avoid "saturated strips". It we had chosen the KAF401E (non antiblooming) we would have had a more sensitive CCD but it would have needed a device to occult the bright objects (Moon, Venus).

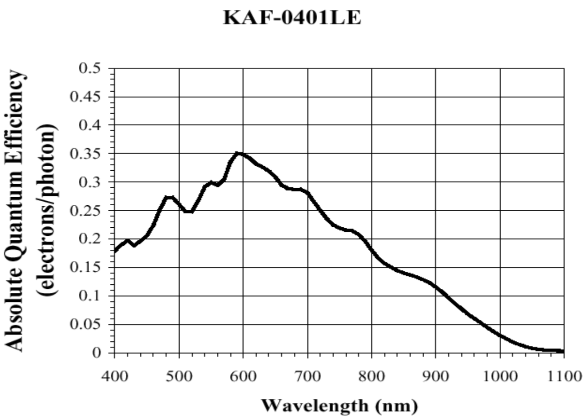


Figure 4 - KAF401LE Absolute quantum efficiency (0 to 0.5 scale)

About the characteristics of the camera, the digitization is made on 32767 levels; the mean value of the bias image is about 3500ADU, with a sigma value of only 2.2.

An interesting point is that the camera can also use other sensors from the KAF series: KAF1602E and KAF3200E (with double and quadruple size): they are pin compatible, and only a simple voltage adaptation must be done. It can be an interesting solution to upgrade the camera if more angular resolution is desired (necessity to adapt also the optics). Note also that an Ethernet extension (Ethernaude) to the camera is currently developed by AUDE association, that would allow to decrease the download time and increase the distance to the control PC.

5.2.2 The fisheye lens

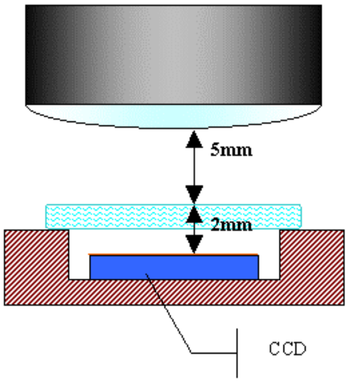


Figure 5- CCD and optics assembly

Pelco 13VA1-3 fisheye lens is optimized for 1/3" chips and the 180° image fits horizontally on a 4.8x3.6mm chip; the KAF-401LE sensor being 4.6x6.9mm, the 180° image will just be a few degrees oversized vertically providing ~530 pixels round image. At the center of the image, the pixel scale is 19'/pixel (on 9um pixels) and at the border of the image, the transversal pixel scale is about 6.4'/pix while the radial one depends strongly on the altitude (to be determined on optical bench when the lens arrives – see later). As a reference, the theoretical diffraction spot at f/1.6 is about 0.6um.

The back focal distance is about 7mm, and the distance between the sensor and he upper face of its protective window is about 2mm, which leaves a 5mm gap (figure). These distances could allow to accommodate a filter should this be considered. However a filter wheel seems difficult to fit in this limited space. The shutter plate has also to be taken in consideration.

The Pelco lens has been received at the end of May 2002. Several tests were made using a digital camera to make test images. The field of view is conform to the specifications: 180° in the 1.6 focal length position.

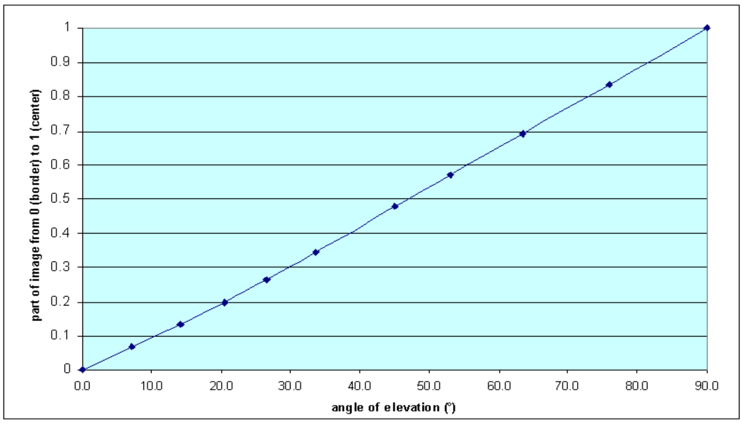


Figure 6 - PELCO lens measured angular projection

A second test was made to check the angular projection (figure 5). An image was made using graduations and I measured the repartition in the field of view. The result shows that the angular projection is almost linear: the fisheye lens is of an equidistant type, as illustrated on the figure 6.

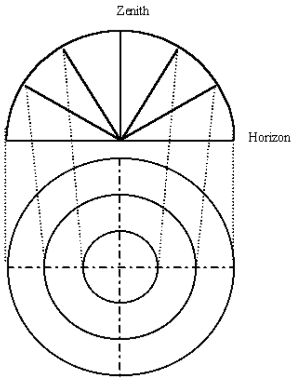


Figure 7 - Equidistant fisheye optics

We then can conclude that the pixel scale will be slightly the same at the center or near the border of the image, i.e. about 19 arcmin per pixel.

Figure 8 - Simulated image of Pelco lens on KAF-401LE

6 The AudeLA Software

6.1 Presentation

AudeLA is a free, open-source astronomical software intended for digital observations (CCD cameras, webcam, etc.). It has been developed by a group of French amateur astronomers and is available for free with its source code for both Windows and Linux platforms.

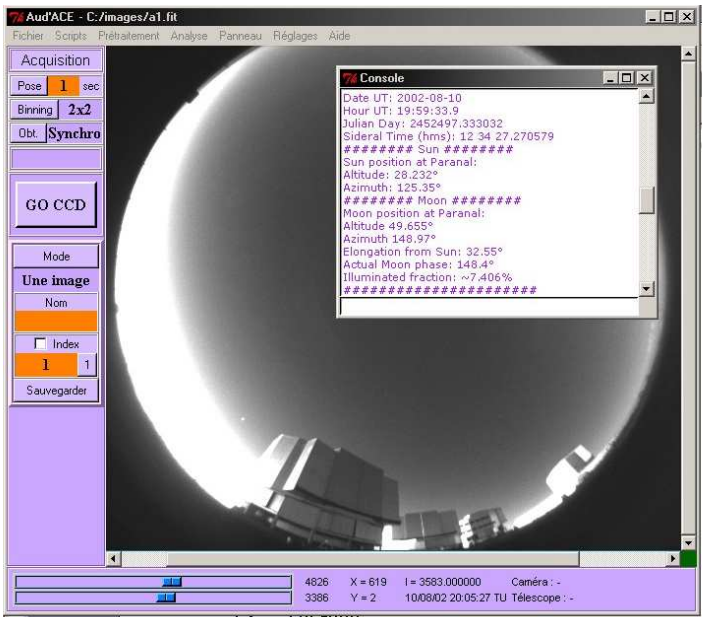


Figure 9 - AudeLA user interface

Its main particularity is its high modularity: using the powerful scripting language Tcl/Tk, the user can develop his own control interface. All the built-in features of AudeLA can be used in such interfaces: image processing, ephemeris calculations, automatic control of cameras and memories, handling of FITS files, etc…

The figure above shows the user interface, called Aud'ACE:

On the left side, an example of a control panel (here the default acquisition panel): it is this interface that can be created and adapted by the user, using Tcl/Tk language (Tcl script language is used to program the actions while Tk language is used for the graphical display of buttons, labels, etc…).

In the middle is the image zone: AudeLA can handle and process FITS file; this format is widely used for scientific imagery and data handling.

We also see the Console, a text window that is used to display information or to send manual commands to the program.

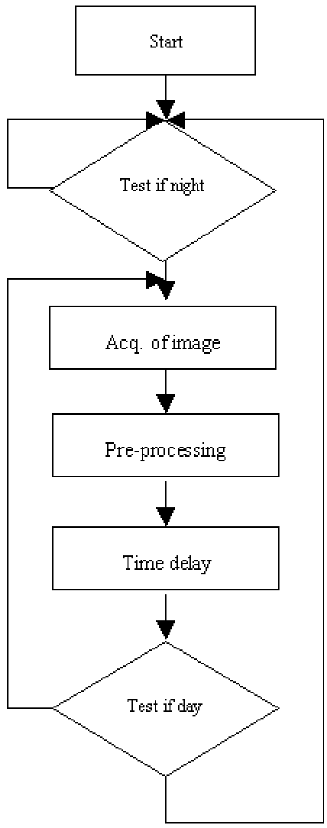
6.2 The two modules

6.2.1 General organization

As seen in the specifications, the software must perform both the acquisition of the images and the display. It has been decided to develop two distinct modules (or panels).

The most important point is the acquisition of the images: the system must be fully automatic, taking images only at night.

The control PC is linked to the camera via the parallel port; the automatic script performs the following typical sequence (entirely run by AudeLA):



1. *Wait for celestial twilight (computed)*
2. *Run a loop script for acquisitions at a dedicated rate*
3. *Acquisition by the camera (possible adaptation of exposure time to the current lunar phase)*
4. *Pre-processing of the images in standard FITS format (offset, dark)*
5. *Optional conversion to a graphical format (jpeg)*
6. *End automatic acquisitions in the morning (computed)… and waiting for the following night*

Basically, the general flow chart would be similar to the opposite one:

It is more flexible to design two different interfaces (one for the acquisition and the other for the animation) as two AudeLA sessions can be run simultaneously. In that way, the automatic acquisition loop would run without any intervention from the user and the animation interface would be available in a second console, for user interaction.

Middle of April, a prototype was ready and tested. It is made of two modules written in Tcl/Tk: cmaude.tcl that performs the automatic loop through several days, with (simulated) acquisitions, and cmanimate.tcl that performs the animation and the individual sequential display of the images. We will describe it in the two following paragraphs.

6.2.2 Automatic acquisition module

As any Tcl/Tk script in AudeLA, the cmaude.tcl module is made of two main parts: a Tk part, describing the graphical interface (position, size of the buttons, text zones, labels, etc...) and a Tcl part with the different procedures called by the actions on the buttons.

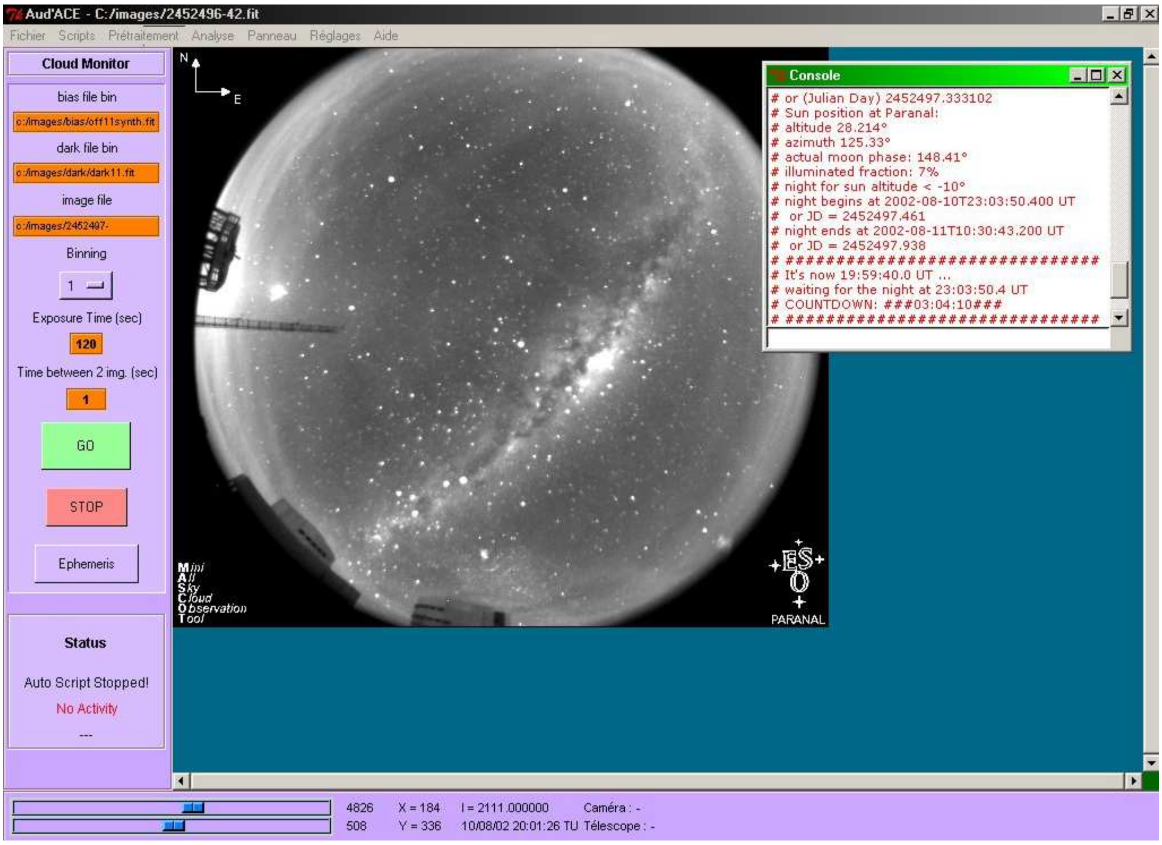


Figure 10 - Automatic acquisition control interface

Here is a description of the interface; it's composed by the following elements:

- Three text zones with the path and name of the bias and dark FITS file (used for image processing), and the name of the image. Though that name appears automatically, the user can also modify it if necessary.
- A choice for the binning: the user can choose if the images are done in binning 1, 2, 3 or 4: that will act on the size of the image and the "apparent sensitivity" of the CCD. That option is mainly used for test purpose.
- Two text zones with the exposure time and the delay between two images: this values can be modified by the user. Note that it can also be modified more permanently trough a configuration file. There are two main exposure times used by the program: a "short" time used when the moon is present or when the sky is not totally dark (at twilight), and a "long" time for the middle of the dark nights.
- The GO, STOP and Ephemeris buttons... as their name suggest it: to run and exit the acquisition script, and to display astronomical ephemeris.
- A status box: here are displayed some information about the status of the program: No activity, waiting for the night, waiting for the following image (countdown), digitization of the image, etc...
- In addition, more complete information is displayed in the Console window

The main procedures are the following:

- CmdGo: called by pushing the GO button, it's the main loop of the program: it calculates the astronomical parameters for the current day (time of sunset and sunrise) and compares it with the current time. If the night is detected, it commands the acquisitions at a regular rhythm, else it waits for the night.
- CmdAcq: called from CmdGo, it prepares the acquisition of an image by the camera (retrieves the exposure time, binning, name of the frame, UT and sidereal time), and writes information in the FITS header when the image is retrieved. The acquisition itself is run by the sub-procedure Acq.
- CmdEphe: called by pushing the Ephemeris button, it displays in the console some current information about Sun and Moon (Altitude, Azimuth, Lunar phase,…).
- CmdStop: called by pushing the STOP button, it quits the acquisition loop at any time.

Various features:

During the acquisition, the program does some operations on the image:

- pre-processing: every image is optimized and corrected by the *bias (offset)* and *dark* image, using the OPT command of AudeLA (automatic optimization). No correction by the *flat-field* image has been implemented, as the result is more hazardous with a fisheye lens, and the first tests didn't show the need to do so.
- windowing: as the image from the fisheye is circular and the CCD is rectangular, the image is cut to reduce its size and make it easier to view. Each final FITS image has a size of 600KB.
- mirroring: the image is mirrored by vertical symmetry in order to have North at the top side and East at the right side, as on the control interface of the telescopes. At this step, a "template" image is overlaid, with a "compass" arrow, the current date and UT time (and two accessory MASCOT and ESO logos).
- JPEG copy: a *.jpeg* image is created, to have an other possibility to view the image, for example using a web browser or a standard image editor. Each JPEG image weight has a size of about 40KB.
- Completing the FITS header: some information is added to the FITS header of each image, such as the current sidereal time or the position (altitude and azimuth) of the four VLT Telescopes at the moment of the image. I'll develop that idea in a following paragraph.

After the first tests, the variables were set to the following values:

- exposure time without moon or on dark night: 90 sec; note that this exposure time can be increase to more than 120 sec without having trailed stars, however I don't recommend it as on a long exposure image, the fast clouds become fainter. 90sec seems to be a good compromise between cloud detection and good S/N ratio.
- exposure time with moon or during twilight: 15 sec; it's the optimal time to have a good S/N ration. With an exposure time of 25-30sec, the antiblooming feature could be inefficient and cause saturation trails on the full moon.
- delay between each pose: 60 sec; however, during the "real" exploitation of the camera, I suggest to use the minimum delay (1sec) to have the most continuous survey of the sky.
- One must also take in account the fixed reading time (digitisation delay) of the camera: about 12sec in binning 1x1, and the pre-processing delay: about 2sec.

All those parameters can be changed dynamically through the mascotConfAcq.tcl file. In addition, the delay between each pose can be modified through the AudeLA interface.

6.2.3 Animation module

The purpose of this module is to allow the user accessing easily the images taken during the night. The basic specifications were to allow the automatic animation of the successive frames, and the “browsing” of the images.

Here is the interface, with a sample image:

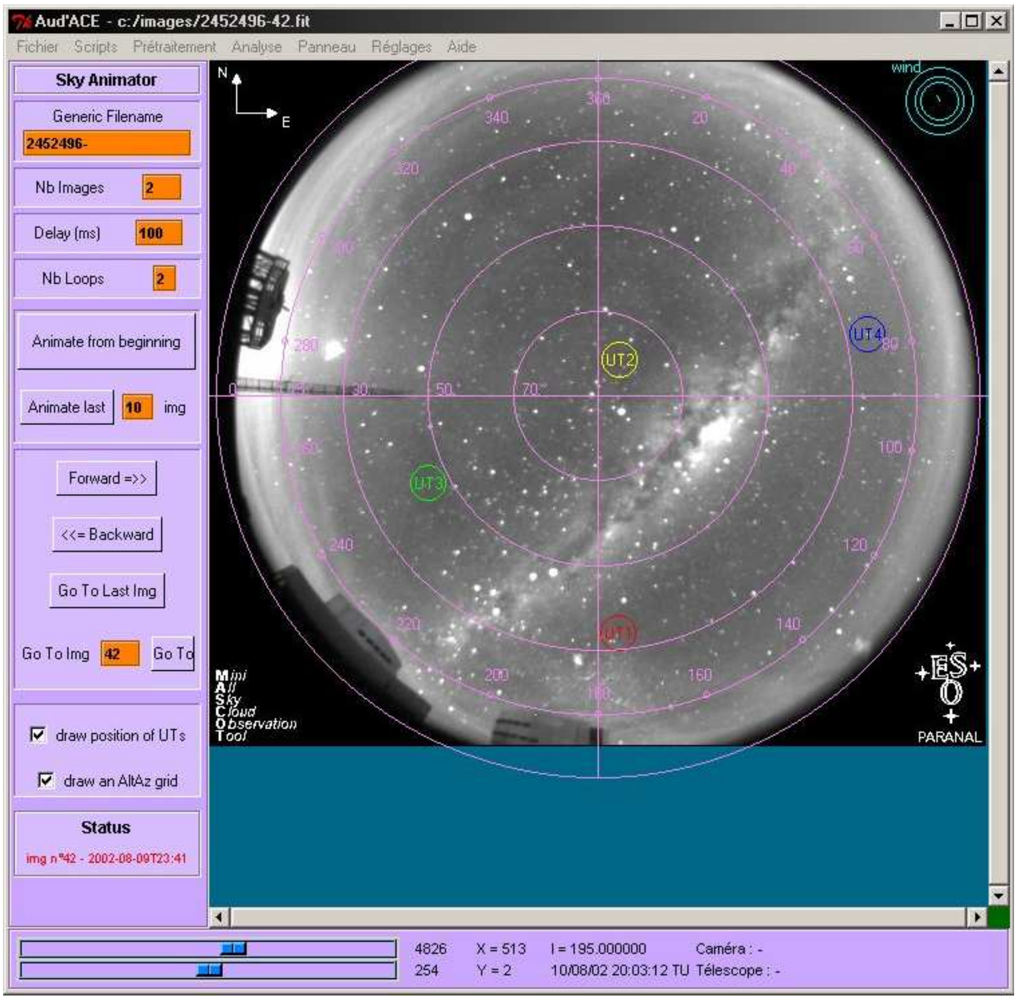


Figure 11 - Animation interface

The graphics interface is made of animation buttons and text entry boxes; the user can choose between animating N images, T times with a delay D between each frame, from the beginning or only the last N images. He can also go to a specific image (with its order number), to the last image available, and look at the successive images with the Forward and Backward buttons.

Note that the display of an animation can take long for large series of images: in fact, before displaying the animation, the program opens each FITS file and loads it in a buffer. Practically, the user will mostly be interested by the most recent images to see the moving of the clouds over the last minutes and the animation will just use the last 10 or 15 images, which is faster to load.

We also see on the control panel two check cases: the user can choose to display over the image an altazimuthal grid, and the position on sky of each telescope at the moment of the image. This last information is contained in the FITS header of each image and retrieved when the image is displayed.

6.2.4 UT's position retriever

As we saw before, the animation panel also displays the position on the sky of all UTs. This information (retrieved at the moment when the image is taken) is contained in the header of the FITS image. To retrieve it, a little utility has been coded in Tcl/Tk, in order to read into the VLT database.

This utility consists in asmcmsGetTcsData.tcl script, which accesses and reads the database, and the MascotUtSky.tcl script, which gives a graphical interface to the program (see figure) and writes the information (Altitude, Azimuth, Status of each telescope) into a text file readable from AudeLA.

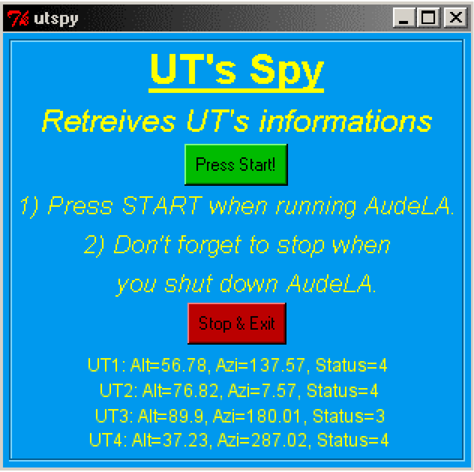


Figure 12 - UTSpy interface

The scan of the database is made regularly (every 2 or 3 seconds) so that the information into the text file is always up to date.

7 Integration

7.1 Housing

7.1.1 Optical adapter

One had to design a simple adapter between the camera and the fisheye lens. It's a circular drilled and threaded piece of brass (see figure)

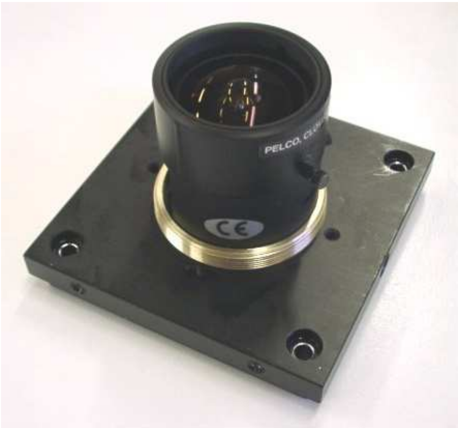
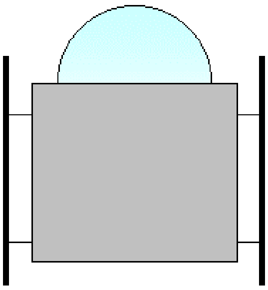


Figure 13 - Adapter between camera and optics

It's threaded at M31.75x0.8 for the outside (Genesis camera top plate) and M25.4x0.8 for the inside (Pelco lens). This part has been made in the Paranal workshop.

7.1.2 Design of the box

The main problem with the box outdoors is the ambient and dissipated heat during the day.



I made preliminary tests with a simple metallic box placed under the Sun during a whole day: the temperature inside can increase to 30-40°C while the ambient temperature is 15-18°C.

If one considers a single metallic box placed under the Sun, the main technique used to avoid the heating of the box by the solar radiation is to use metallic shields placed some centimeters above the box plates (technique used mainly in meteorological equipments). The shields are attached to the box only by little metallic rods. This is enough to keep the box at the ambient temperature. In addition, the camera will only send its images at night, and it doesn't needs to run during the day.

We then decided to use a photocell module (often used in street lightning), that switches on the power supply when the night comes. This prevents the camera and the Peltier module to overheat during the day. In addition, a fan allows airflow circulation at day and night.

For the box itself, we use a model already available at Paranal for electrical equipments and which is of the right size (40x40x20cm) to accommodate the camera, its power supply and other accessories..

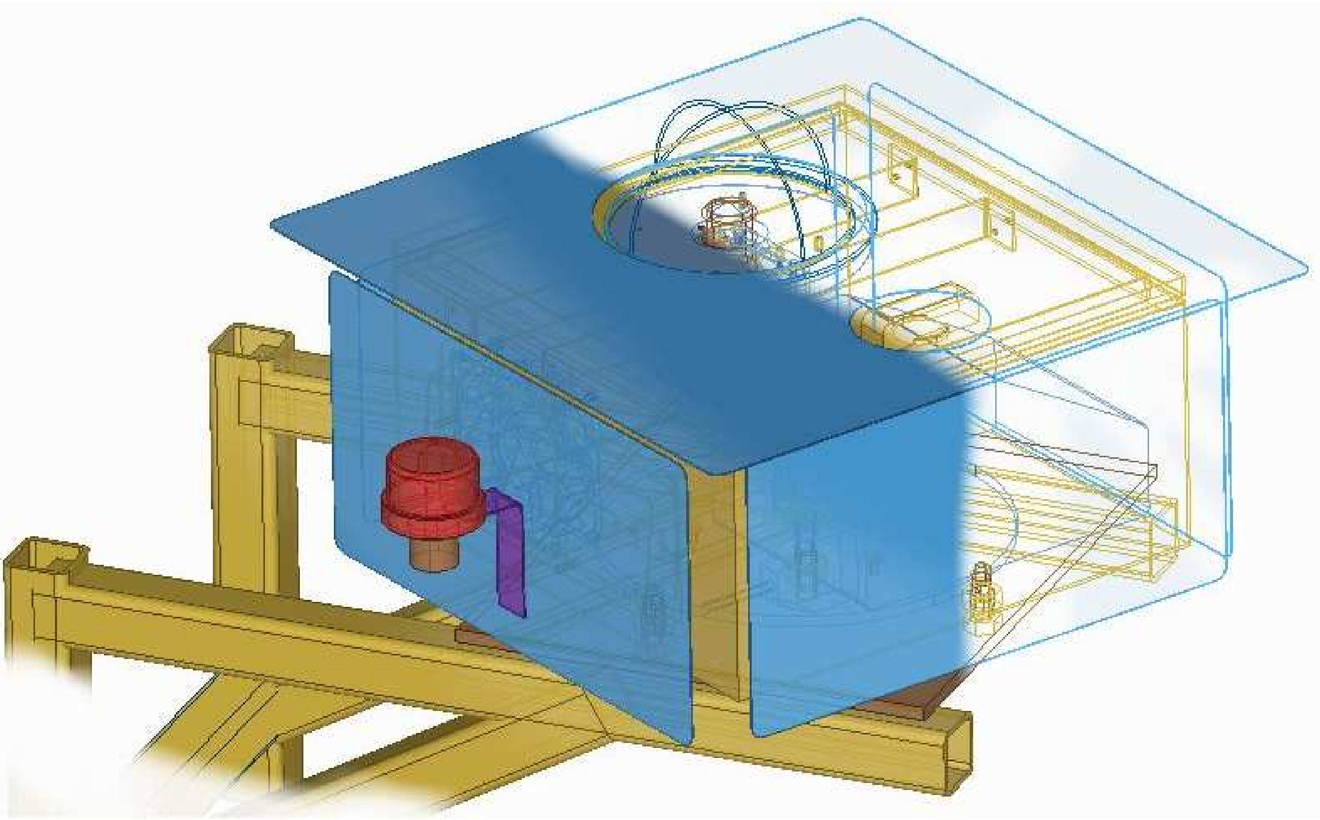


Figure 14 - CAD model of MASCOT

Once the box model was decided, I began to make a CAD design (using VariCAD software) of the box and its equipments in order to manufacture the missing parts (protective plates, support of the camera, support of MASCOT, etc...) and verify the correct integration in the box.

Figure 15 - Equipping the MASCOT box

7.1.3 Protective cap

A concern was raised, about the aging of the fisheye optic exposed for a long time to solar radiations. As this optics may have glued lenses, a continuous solar heating could cause lenses to detach or glue to opacify. To prevent any risk of overheating, I designed a moving cap that protects the lens during the day and opens automatically at dusk.

It is activated using the same photocell that is used to activate the power supply.

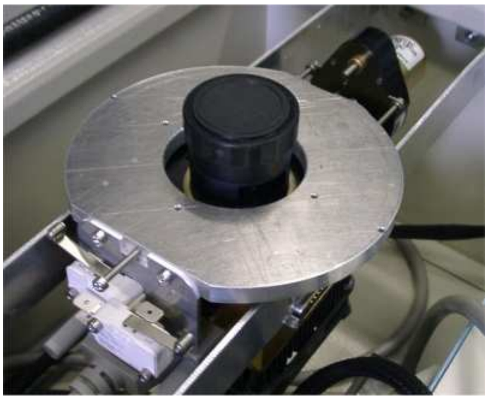


Figure 16 - Base of the protective cap

The motion of the protective cap is provided by a DC motor and reducer, and two switches stop the opening and closing movements.

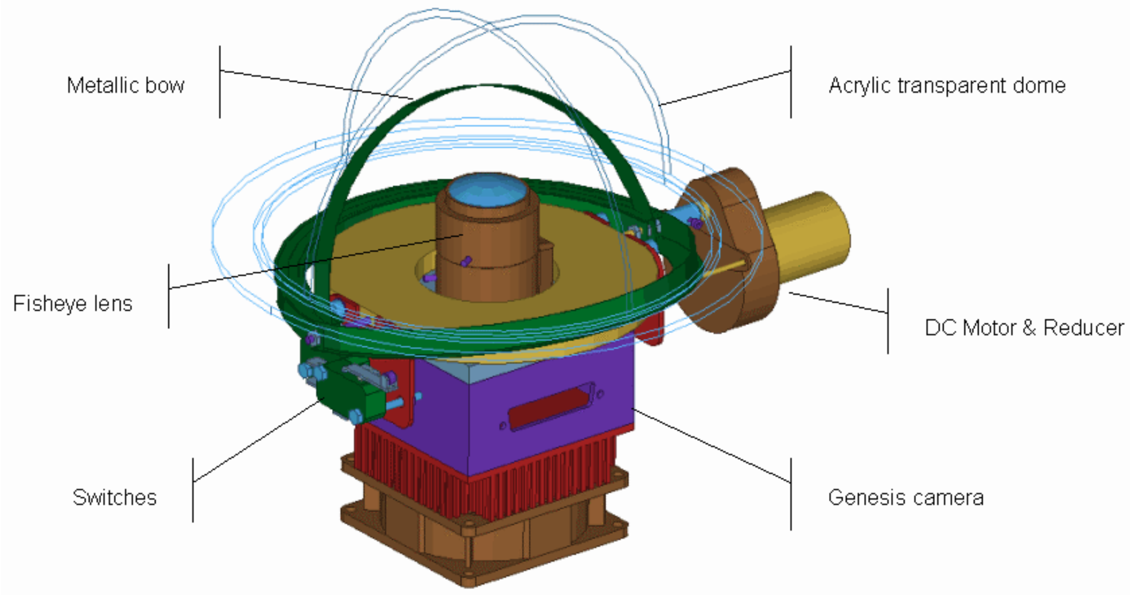


Figure 17 - Protective cap system

The cap itself is made of three metallic bows, one of which is directly linked to the motor axle (the two others remaining free). A plastic sheet covers the three bows and makes the protection.

The electrical wiring (detailed in appendices) uses a relay activated by the photocell as opening/closing signal; with the addition of the two switches, this gives a simple and fully automated mechanism. Two additive toggle switches allow the user to pass in "manual mode" in order to open the cap during the day for maintenance purpose.

Figure 18 - Protective cap in opened and closed positions

7.1.4 The support

The support consists in two parts: one fixed, to support the weight of MASCOT and a mobile one to orient the box: it is a circular plate with one central screw and three screws at 120°. This is needed to display properly the position of the UT's, as the vertical axe of the CCD must be oriented north-south; in addition, the three screws also allow to have the camera horizontal.

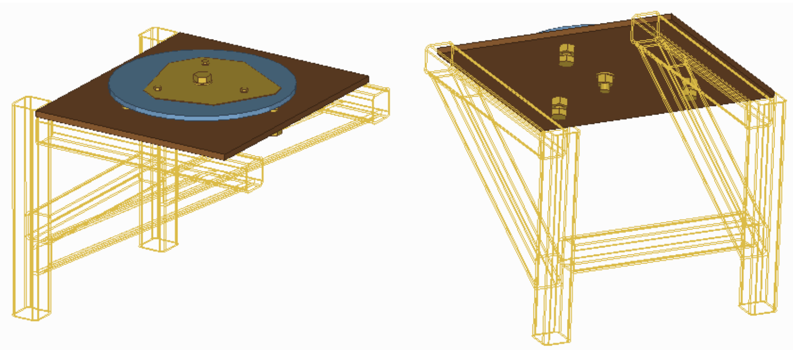


Figure 19 - Basic design of the support

Figure 20 - The support on the side of the Meteorological Hut

8 Location

8.1.1 Basic criteria

The first condition to determine the best place for the MASCOT is of course to have the best visibility on the sky and on the horizon. In addition, according to the observers, clouds often come from the north, so that the northern horizon must be particularly clear.

The second criterion was to minimize the connection length between the camera and the PC: it is a parallel cable, and it should be advisable to have a short length to avoid interferences on the image. The PC must be connected on the VLT network.

Finally, we considered it could be quite important to have a direct view in the direction of Antofagasta and of the nearby mining exploitation.

In fact, at night, some source of artificial lights are visible in some conditions:

- The nearby mine La Julia: situated some thirty kilometers south of Paranal, its lights are directly visible from the observatory, and it's important to monitor it.
- Antofagasta: 200000 inhabitants town, situated about 120km north of Paranal, it's lights are not directly visible but we can sometimes see a diffusion by the low haze of a reverberation on the higher clouds.
- La Mina La Escondida : situated about 200km east of Paranal, in the Cordillera, it's lights are sometimes visible by reverberation on the high clouds.

And we can add the rarer natural source of thunderstorms lightings over the Cordillera: despite the distance, the lightings can be intense with a great activity.

For all those reasons it can be better to have a clear view to north, east and south horizons.

8.1.2 Looking for a site

During the definition phase, several sites have been considered, such as the Control Building roof or the DIMM telescope tower. However, it was preferable to determine it with the real optics.

The first tests have been made after receiving the fisheye lens, using a digital camera in macro mode and a simple hand made adapter that maintain the fisheye lens at the proper distance from the camera objective.

I took several images in various places of the platform. I then rotated the images in order to orient them all in the same way.

On the following page we can see the different places and their corresponding test pictures.

The Control Building roof could be a very good place, as it is situated far from the UTs (UT1, UT2, UT3 are at the same azimuth) and the horizon is particularly clear. However, the access to the roof is not easy and for security reasons it has been decided to abandon that location.

The second best location is close from the DIMM telescope, on the North side of the platform. Three telescopes are also in the same direction, and the North and East horizon have a particularly free view. However, the VST is the closest building, and it could hide part of the sky when built.

It has been decided to install the MASCOT on the roof of the meteorological hut: this is a container situated about 10 meters east of the DIMM tower; it is connected to the VLT network and can be used to shelter the PC.

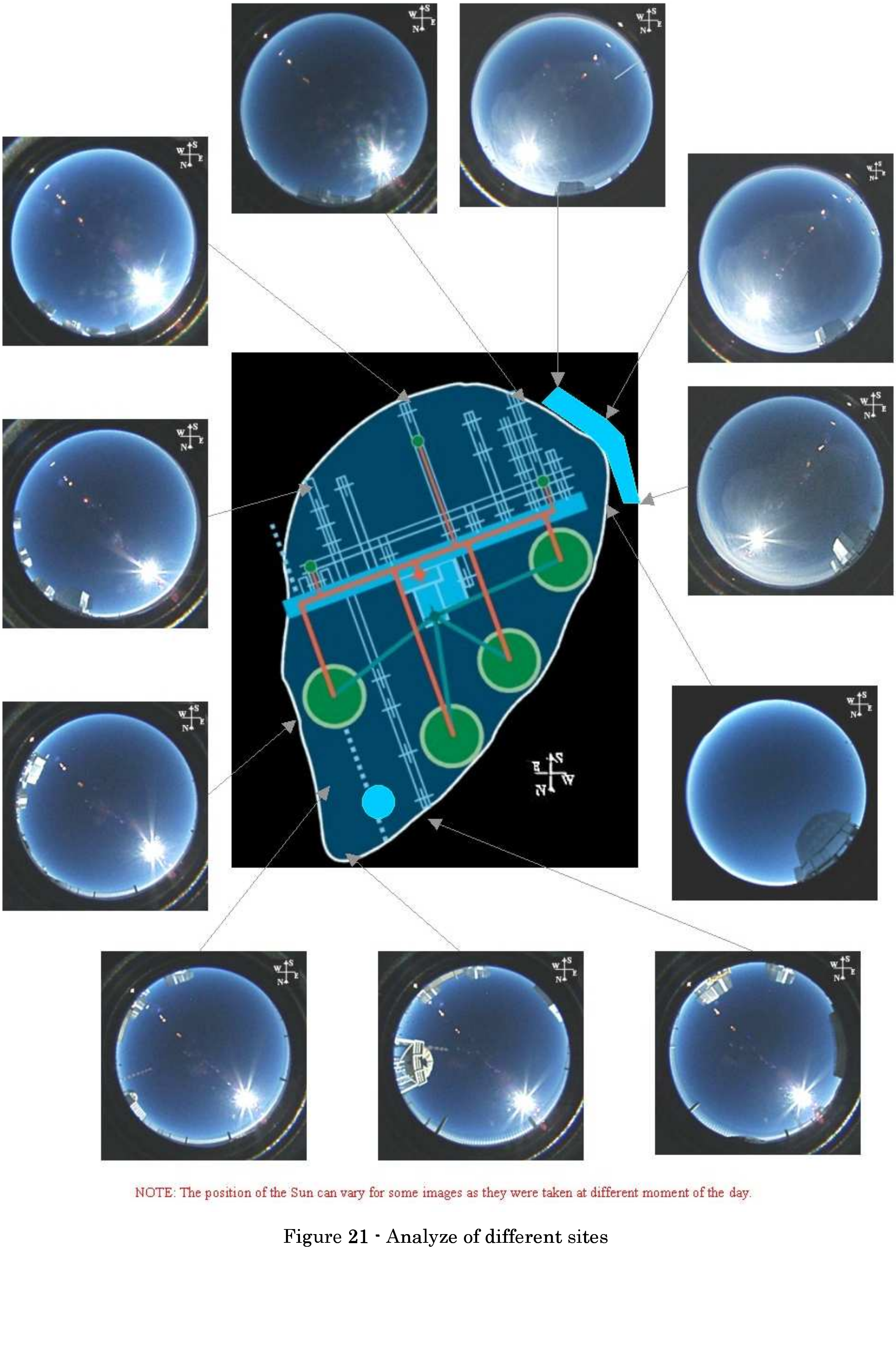


Figure 21 - Analyze of different sites

9 Results

9.1 Preliminary tests

The first tests have been made when the camera and the fisheye lens arrived at Paranal, at the beginning of June 2002. It consisted in testing the acquisition of the camera and adapting the software that had been written to the "real" camera (and not a simulation).

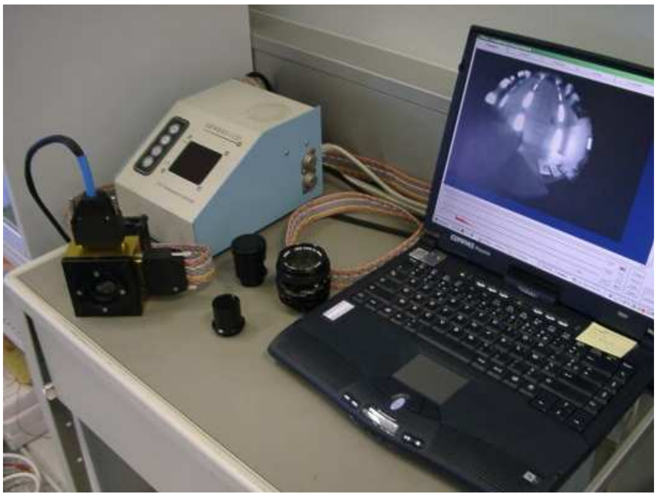


Figure 22 - Testing the camera and software indoors

The first "real" observation on the sky was made on 7th June 2002, using the automatic script. As the protective box was not built at this moment, the images were taken through the Engineering Office's window (see picture).

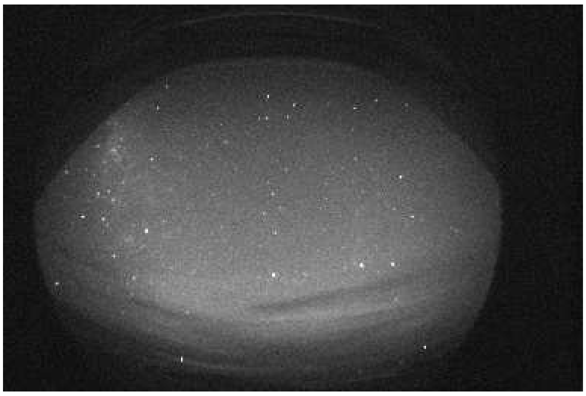


Figure 23 - (almost) first light

On that image, one can clearly see part of the Milky Way, and clouds (dark over the clear background). This first test allowed to validate the good functioning of the camera and the fisheye lens.

During the month of June, several other tests were done to check the evolution on the hardware and on the software.

9.2 Quantitative analysis of the images:

9.2.1 Images without Moon:

First here are some values measured on a standard image, posed 90 seconds:

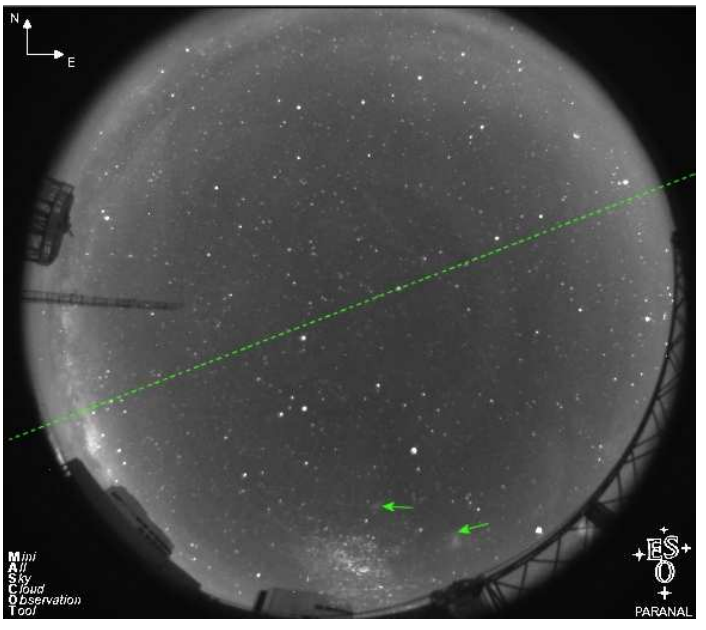
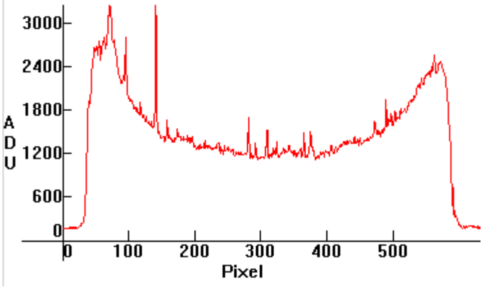


Figure 24 - MASCOT image; analyze without Moon

- Dark parts (non exposed parts around the image): mean level 150ADU
- Background sky, center of the image: mean level 1100ADU
- Background sky, border of the image: mean level from 1650 to 2400 ADU
- Most bright star: maximum level about 22000 to 24000ADU;

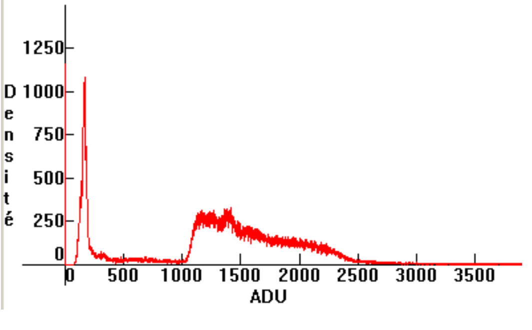
For all the stars, and a well focused image, the FWHM ranges between 1.5 and 2.3; can certainly been improved by a more precise focalization.

Here is a cut across the image:



We can remark the non-linearity of the background sky from the center to the border of the image (the more intense irregularities on the left are due to the setting Milky Way; the other are stars). This effect may be due to the air mass and the haze/dusts that are more important close to the horizon, and diffuse more the light.

Here is a histogram of the entire image:



We remark the high peak at about 200ADU, due only to the dark part around the image. We also see that the histogram of the image itself ranges from 1000ADU to 2500ADU. The upper values due to more bright stars are equally distributed from 2500ADU to the maximum, about 24000ADU (not represented on the histogram).

Note also on the image the two Magellanic Clouds (green arrows) and the metallic structure on the right, that is just a mobile crane that had been parked close to MASCOT for some times.

9.2.2 Images with Moon

Now, we analyze a standard image taken with the Moon:

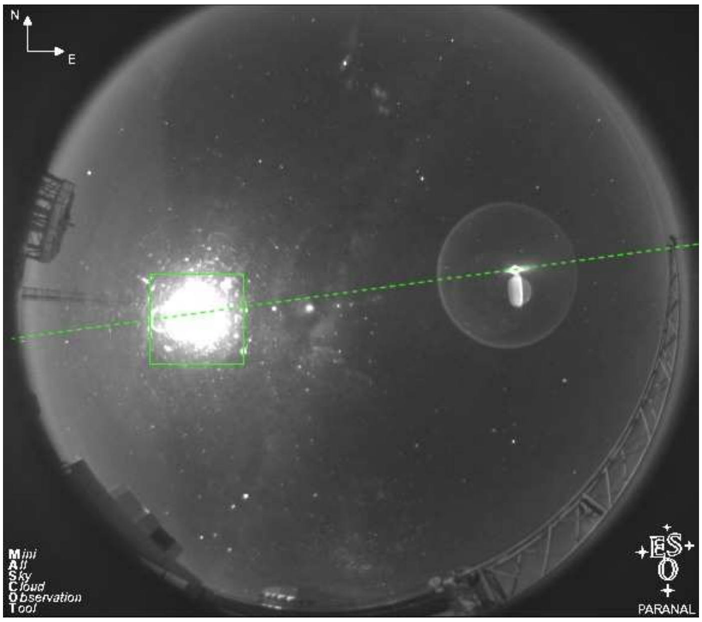
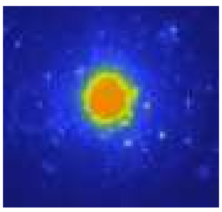


Figure 25 - MASCOT image - analyze with Moon

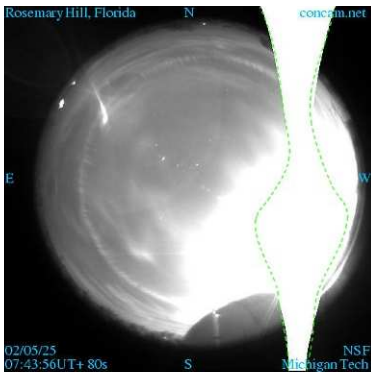
The exposure time here is 15 seconds. Here are the main measures:

Dark parts (non exposed parts around the image): mean level 240ADU; higher than without the Moon, due to the reflections and the high level of the Moon.

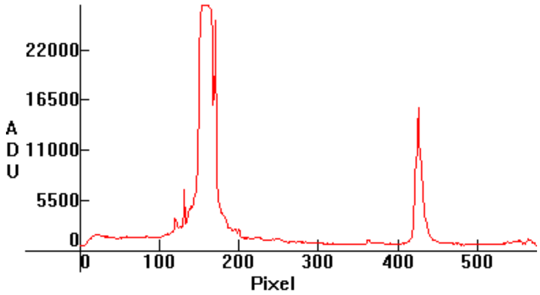
- Background sky, darkest parts of the image: mean level 500ADU
- Background sky, border of the image: mean level from 700 to 900 ADU
- Most bright star: maximum level about 6000 to 9000ADU;
- Moon: center (saturated and "anti-bloomed") about 27000ADU;
- Moon: around the Moon, reflects from 5000 to 15000ADU;
- Note also that despite the Moon, the Milky Way is still visible.



Here (left) we see a zoom on the Moon (green square) in false colors. Theoretically, the disk of the Moon should contain on 2 pixels. However, we see that the high luminosity of the Moon is contained on a diameter of about 15 pixels. The mean value in that saturated area has been "lowered" to about 27000ADU (with a sigma of 200) by the antiblooming feature. We can be sure that without an antiblooming sensor we would have a huge trail due to the saturation, just like on that all-sky picture (right) from CONCAM project (saturated zone delimited by dashed lines):

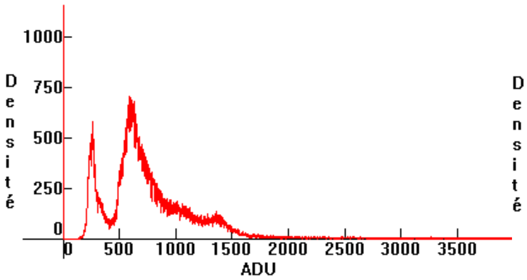


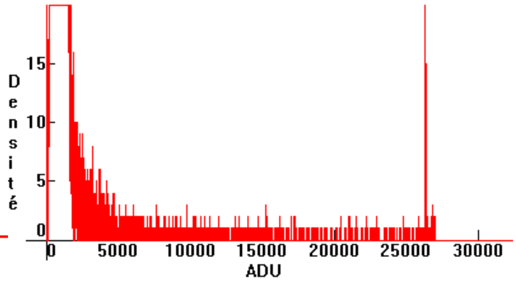
The cut across the image is quite different from the one made without the moon: the background sky is more linear and it's of course dominated by the moonlight: here we see the high peak of the Moon (left) and the lower peak due to the main reflect of the Moon in the optics.



The histograms are quite similar to the previous one, as the influence of the Moon is not so high compared to the whole sky. So we also see a first peak due to the black areas outside the image and a second large zone between 500 and 1700ADU due to the background sky.

On the second histogram, we see the repartition of the intensities of the bright stars and of the Moon from 5000 to about 27000ADU. We see that there is no intensity higher than 27000ADU, as the antiblooming feature sets to 27000ADU all the intensities higher than 27000 and then creates a "forbidden zone" between 27000 and 32000ADU.





9.2.3 Clouds and airglow

Here we make an analysis of the images presenting clouds or airglow (atmospheric lines emission – see 10.6)

First, here is an analysis of the airglow: it's visible as a succession of stripes in the sky, slightly more luminous than the background.

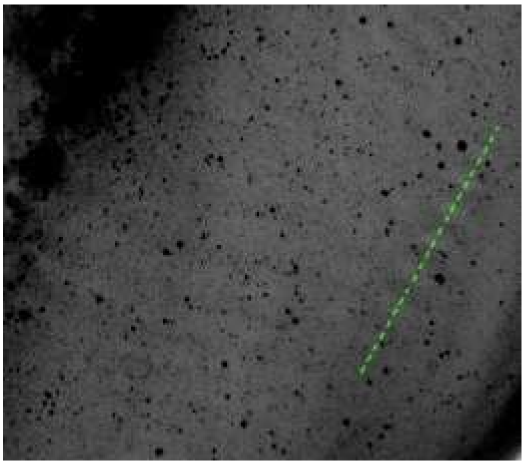
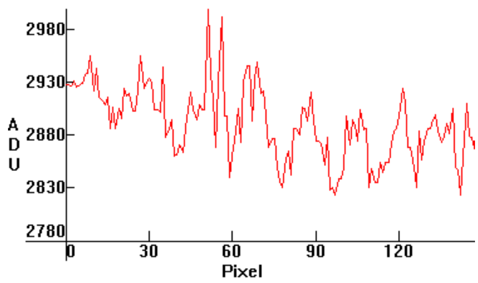


Figure 26 - Typical airglow stripes (high-contrast negative image)

Here is a cut of the airglow stripes on a 30sec exposure image: some stars are disturbing the graph, but we can clearly see a wave variation between the background (about 2840ADU) and the airglow (about 2900ADU for the maximum).



Here is now a typical image with clouds and Moon:

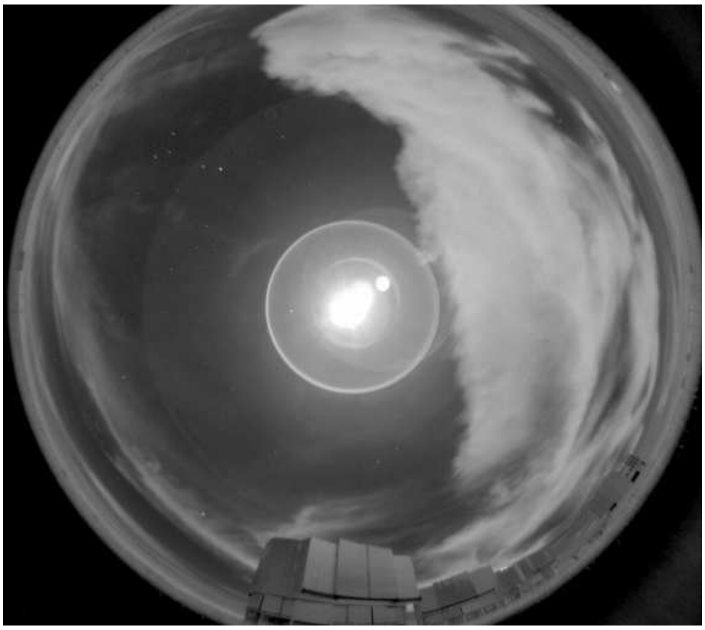
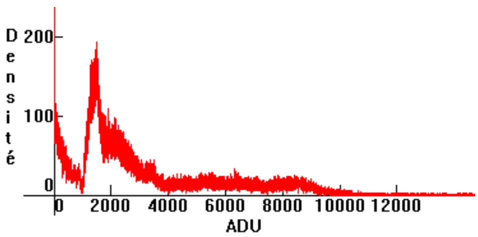


Figure 27 - Clouds under the Moonlight

In that case, the clouds are identifiable without any problem. The mean value of the background sky is about 1800ADU, while the clouds range between 4000 and 9000ADU. This appears clearly on the histogram: we find the peak of the background sky and a "plane" part from 4000 to 9000ADU representing the clouds.



9.2.4 About the dome quality

The camera is placed under an acrylic dome from Edmund Scientific. That dome is about 5mm thick. Visually, the optical quality is quite good, however some little scratches or points are visible. The thickness of the dome seems also to produce a geometric distortion of the image. I made some tests to check the influence of the dome over the pictures. The test was made indoors in order to have a geometric pattern all over the image (in that case, the ceiling of the office).

Figure 28 - Comparison with (left) and without (right) acrylic dome

On the first picture, we see that the little dusts and points on the dome produce a few defects and diffusions on the image.

To analyze the geometric distortion on the image, I made a division of the image with dome by the image without dome:

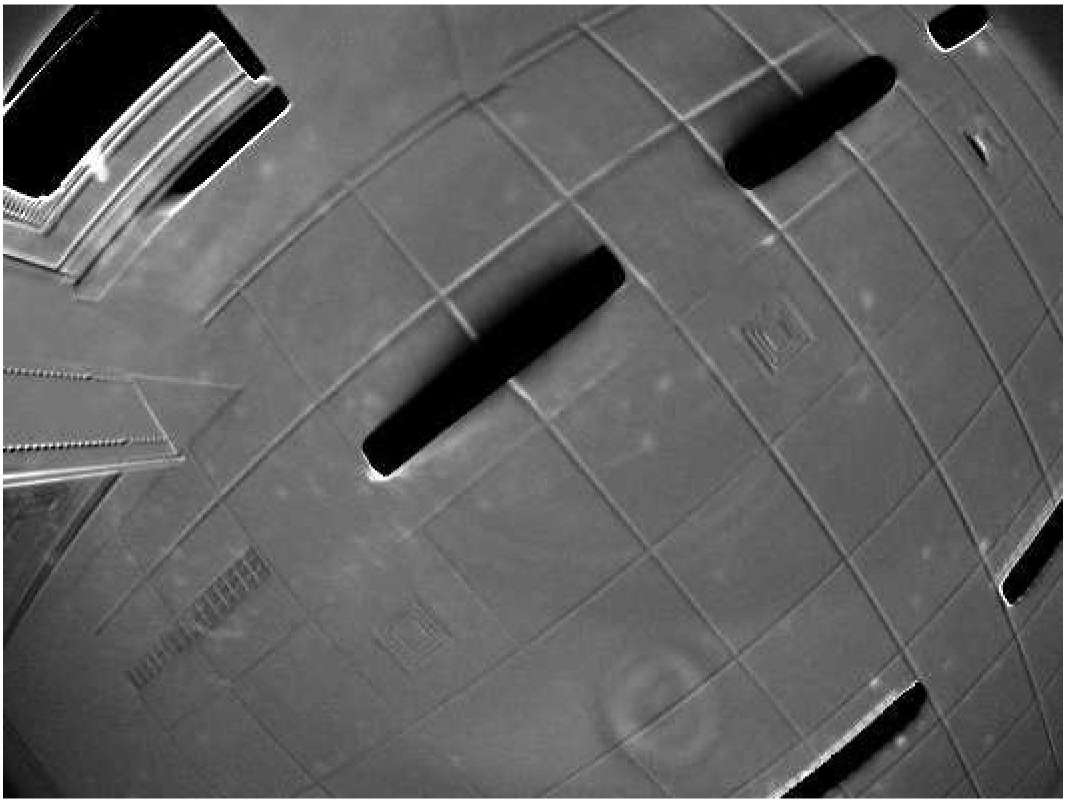


Figure 29 - Division (with dome / without dome)

On this divided image, the distortion is evident: we see that the picture with the dome is slightly more contracted. However, this contraction is constant and quite negligible. We also see the little dusts and the reflect of the lens over the internal face of the dome (at the center).

The tests on the sky showed that the pictures are quite good on a sky without Moon; however, when the Moon is present, its brightness makes some patterns on the images. Those patterns are easily identifiable and very specific (can't be confused with clouds or other phenomena). However, if their presence is considered as annoying for the interpretation, it will be good to investigate for a higher quality dome (maybe a glass dome).

9.3 MASCOT functioning

The protective box was almost built at the beginning of July and I could make the first tests with the "final configuration": the photocell, the Linux PC, and the camera inside the box.

Figure 30 - Mascot installed outdoors

The final decision about the location was taken at the end of July and the support was adapted to the meteo hut roof.

9.4 Integration to the VLT Network

The main work after the installation of the camera on the meteo hut was to make the tests to run and use it from the Control Room.

The first communication test showed a very slow speed: about 10 seconds to load an image remotely from the Linux PC to an X-machine display in the Control Room. The ftp transfer of the images also showed some irregularities on the transfer rate. After some investigation, the configuration of the network card in the PC was changed by SERCO people and the rate became much more normal: less than 1 second to load an image. This rhythm is still slow to display a fluid animation, but a correct survey of the sky can now be done from the Control Room.

An other problem appeared on the display of the images: while on the Linux PC the gray scale is very smooth, on the X-machine, the gray levels are very few and gives a more difficult interpretation of the image. There are various solution, one of the most advanced being to use the RTD software (Real Time Display) which is the standard VLT viewing software and that display correctly the images.

From the middle of August, MASCOT is run from the Control Building without problem; some improvement are still to do (add keywords in the FITS header, adapt the RTD viewer,...) but it's exploitable.

9.5 Further work

Some ideas of improvement could be:

- The use of AudeLA version 1.2: this version will be available during Autumn 2002 (beta version is yet available). This version support Tcl/Tk version 8.3 (the version used by the VLT software) and has some new features such as the use of user palettes. Release to check on http://audela.ccdaude.com.

- The use of filters: this could help for example to increase the contrast of some specific atmospheric lines.

- Adding a video movie built during the night and consultable through a HTML browser (no need for a specific browsing software).

- Etc…

10 A view on the images

Here is a compilation of some images taken from the beginning, showing different phenomena detectable with MASCOT.

10.1 Clouds

The main purpose of MASCOT was to monitor clouds… here are some pictures showing clouds over Paranal. On the first one, the Moon lightens the clouds so that they are clearly visible. We also see that the high luminosity of the Moon produces internal reflection inside the optics.

On the second image, we see effects of the moonlight on the atmosphere: ice crystals in the high-atmosphere creates a "22° halo" around the moon, and two "Moon-dogs" are visible too. Note also the dark clouds over the bright background.

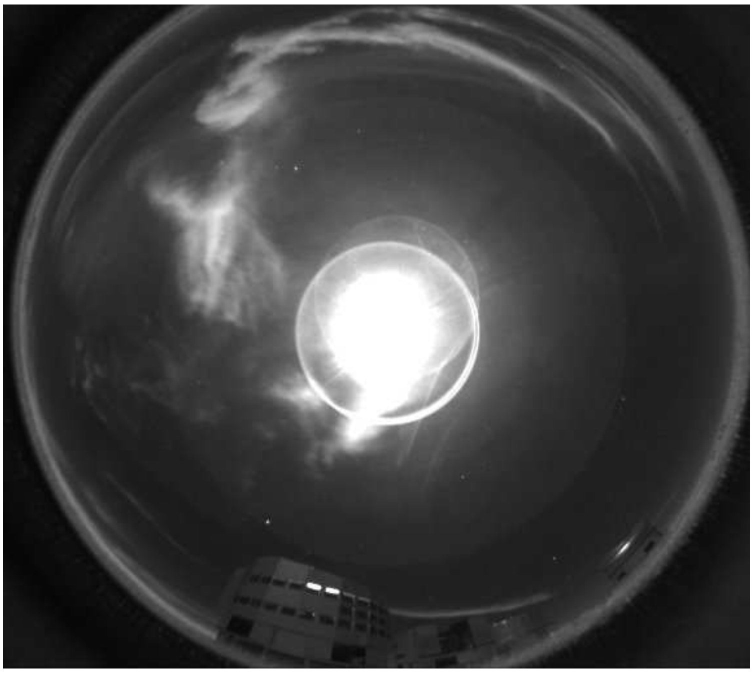


Figure 31 - MASCOT image: clouds & Moon

Figure 32 - MASCOT image: halo and Moon-dogs

10.2 Planes and contrails

Planes are well detected, as a blinking or double light trail; such a detection can be useful to analyze if a plane passed close from a telescope pointing position.

The contrails are as visible as the clouds. As their motion is quite slow, it is also possible to foresee their appearance in front of an observed field.

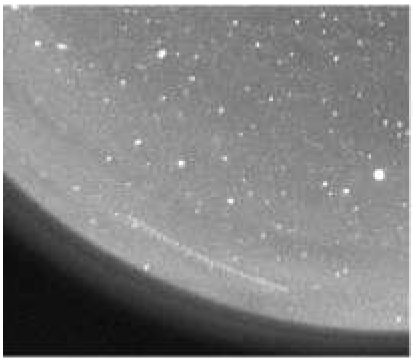


Figure 33 - MASCOT image: plane lights

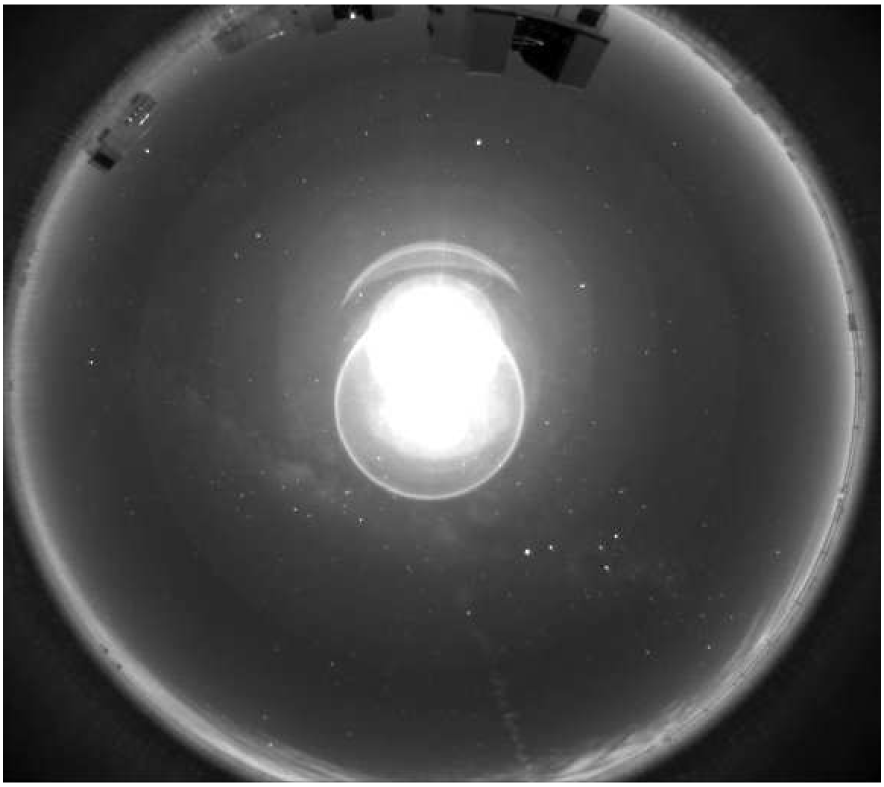


Figure 34 - MASCOT image: Moon and a plane contrail

10.3 Artificial satellites

A thin satellite trail, quite similar to the plane's one. Only the brighter are visible. Note that their expected motion can also be calculated.

Figure 35 - MASCOT image: a satellite trail

10.4 Artificial light pollution, the nearby mine

Some sources of artificial light pollution are sometimes visible. The following image is a median of seven images (15 minutes delay between every image) taken on a night without Moon and with some low altitude clouds.

Figure 36 - The lights of the Mine "La Julia"

The stars almost disappear by the median operation, while the fixed details remains: we clearly see the clouds illuminated by the mine La Julia. That kind of image, realized regularly can permit to make a survey of the evolution of the light pollution.

10.5 Shooting stars

Shooting stars are often seen on MASCOT images ; they appear as more or less irregular trails, easy to identify.

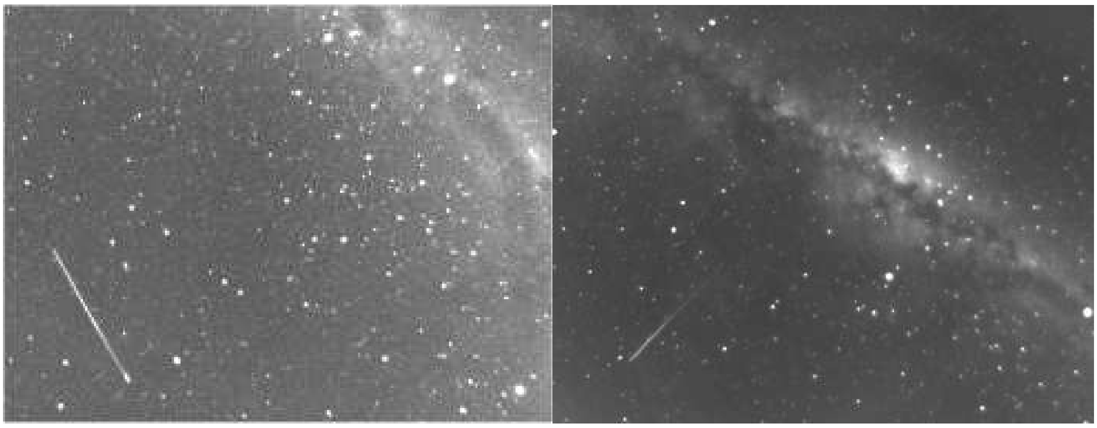


Figure 37 - MASCOT image: two shooting stars

Figure 38 - MASCOT image: a bright explosive shooting star

10.6 Moon

Visible as a very bright light. The moon itself and some surrounding pixels are saturated, but the antiblooming feature of the CCD sensor limits this saturation. However, the image is best viewed in logarithmic scale because of its large dynamics. Note also that the moon gives internal reflexes in the fisheye lens. Nevertheless, the shape of those reflexes is very specific and doesn't disturb the identification of the clouds.

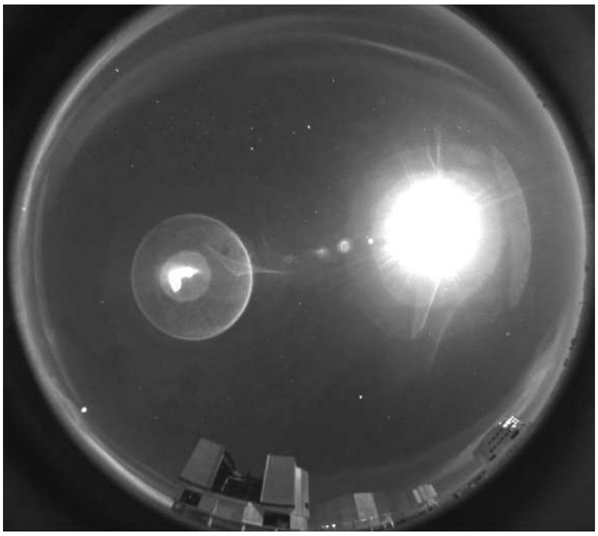


Figure 39 - MASCOT image: Moon and clouds

10.7 Airglow

This effect is due to an emission of the atmosphere in some spectral lines (mainly OI @ 557nm but also OH, OII, OIII, Na) that produces a wave structure (also called "acoustic gravity waves"). The phenomenon occurs in the high atmosphere (80-100km), and produces very characteristic shapes much more visible on a movie, as they move quickly. The waves are the result of oscillations in the atmosphere due to storm fronts, perturbations,… This effect is low and almost never detected with naked eye, but the "oscillations" have been reported by astronomers.

As a mater of comparison, the second image shows OH emission taken above Millstone Hill (Massachusetts) with the Boston University All-Sky Imager. (document from Dr. Steven M. Smith works : http://vega.bu.edu/research.htm)

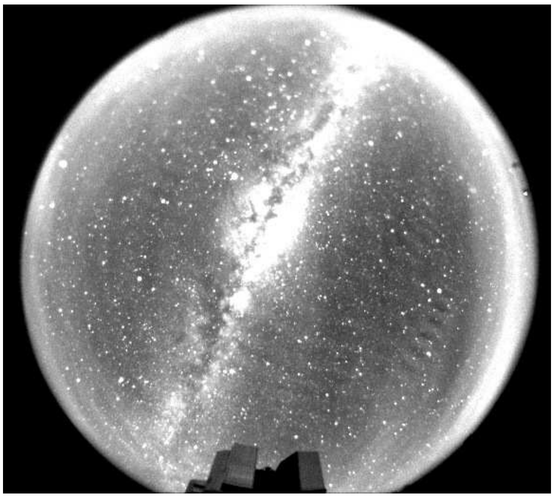


Figure 40 - MASCOT image: airglow emission (unfiltered)

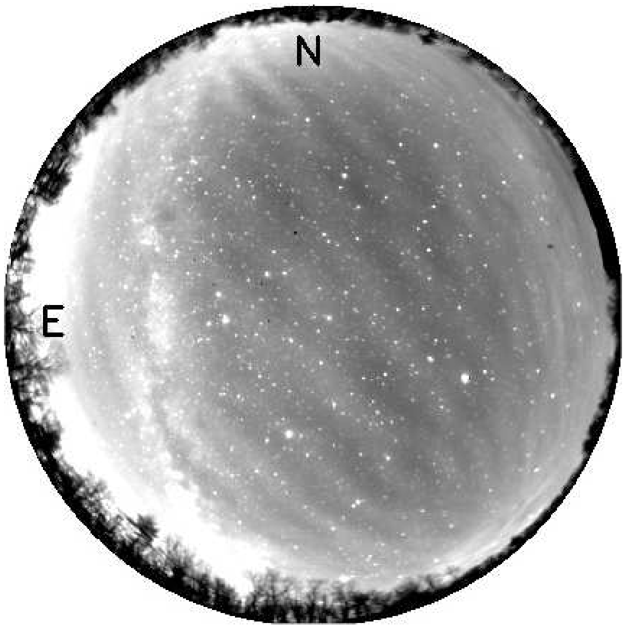


Figure 41 - Typical airglow image (OH filter) - Boston University

10.8 Stars and nebulae

The first image is a trichromic composite of three images taken through narrow band R, V, B interferential filters. The red line is H-alpha emission line and shows the nebulae close to the galactic plane. It also seems that the zodiacal light is visible on the ecliptic plane (under the Milky way).

The second image is a typical 60 sec exposure without the Moon. Of course many stars are visible, despite the poor angular resolution (19 arcmin/pix). The minimum detected magnitude for a 60 sec. unfiltered exposure has been evaluated to be about Mag 6.5.

The Milky Way is very intense and make a very esthetic picture; the effect is particularly impressive on a full-night movie, with the Milky Way slowly passing by the sky.

Figure 42 - MASCOT image: composite color image

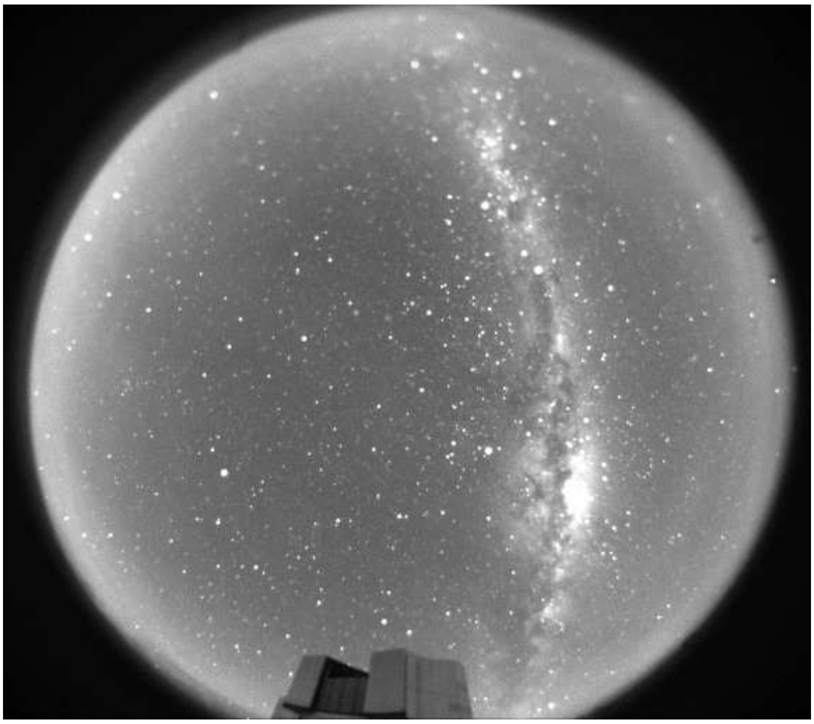


Figure 43 - MASCOT image: Milky Way and deep-sky

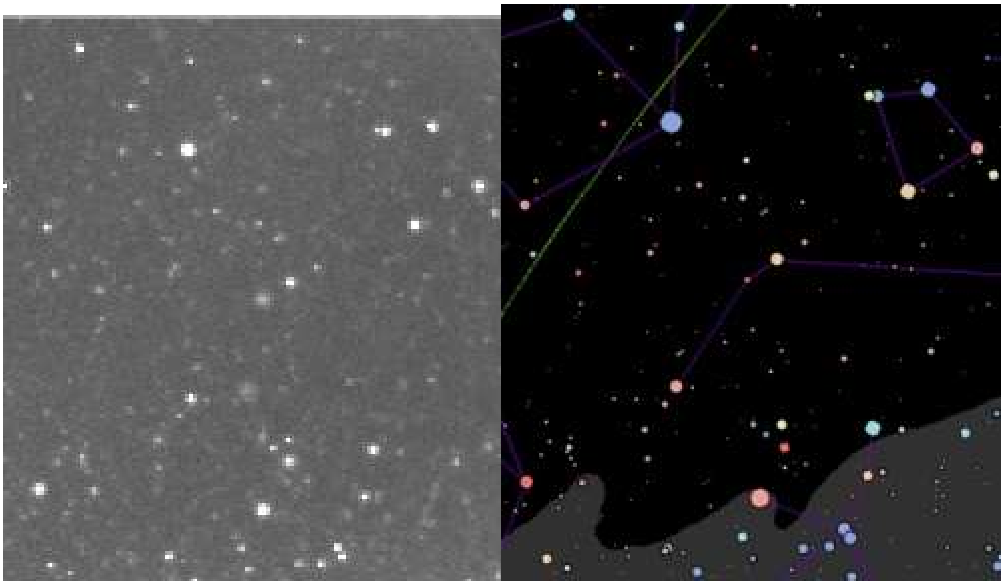


Figure 44 - MASCOT image: detail of an image and corresponding star map

The third image (above) is a detail of the second one near the zenith. A star map is also shown for comparison (with the faintest stars at Mag 6.5). We also see that the detection of the stars varies strongly with their spectral type: for the same magnitude, the red stars are slightly more intense than the blue ones. We also see the effect of chromatism of the fisheye lens: while the blue stars are well focused, some red stars are out of focus (see at the center of the field).

Now, here is a comparison between an unfiltered image of the Milky Way and a filtered one, using H-alpha 10nm filter. The H-alpha image is a composite of several image, and the fisheye lens gives a distortion on the border of the composited image. It's interesting to see the strong emission of some nebulae in H-alpha, which is not seen (lost in the background sky) on the unfiltered exposure.

Note particularly the extended Hydrogen cloud around Zeta Ophiuchi, known as LBN 30, which is so dim that it's not visible on the unfiltered image (dashed red circle).

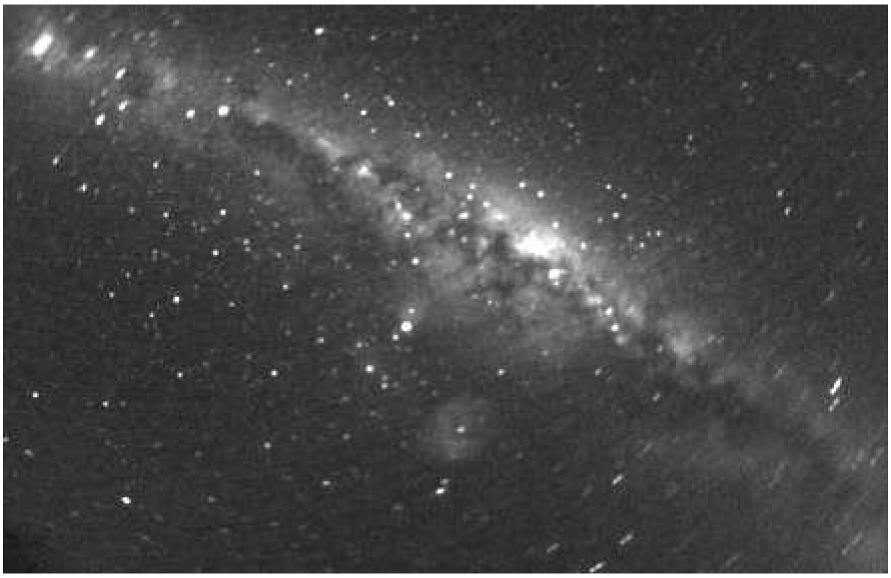


Figure 45 - MASCOT image: H-alpha composite image

Figure 46 - MASCOT image: Visible unfiltered image

11 Conclusion

This work has permitted me to develop an entire system, from the definition of the specifications and the investigation to the programming of the control software and the integration of the system. It was an enriching experience to work abroad during six month in an international context and to see the operation of Paranal Observatory. It was also a very good occasion to practice both English and Spanish through the contact with all the people involved in that project: instrumentation engineers, scientists, optical team and software engineers.

The investigation step has been interesting by analyzing existing similar systems and corresponding with persons involved in similar projects. I also could improve my knowledge about Tcl/Tk script language and programming.

During the supply delay of the equipment, I built an optical bench using lasers to measure optical transmittance. After tests and calibration, we used the bench to verify the transmittance of FORS instrument.

The MASCOT instrument will probably be duplicated for La Silla Observatory; this camera is the first step to a more complex system to evaluate the photometric quality of the sky in field of view of each UT.

Ce travail m'a permis de développer un système complet, depuis la définition des spécifications et la recherche de l'équipement jusqu'à la programmation de l'interface de contrôle et l'intégration du système. Un tel travail à l'étranger, dans un contexte international fut une expérience enrichissante, qui m'a aussi permis de découvrir le fonctionnement de l'Observatoire du Paranal. Ce fut aussi une excellente occasion de pratiquer l'Anglais et l'Espagnol, a travers le contact avec les personnes impliquées dans le projet : ingénieurs instrumentation, scientifiques, opticiens et ingénieurs informatique.

L'étape de recherche fut intéressante de par l'analyse d'appareils similaires existants et le contact avec les personnes impliquées dans de tels projets. J'ai également pu développer mes connaissances en langage script Tcl/Tk et programmation.

Les délais d'approvisionnement du matériel ont été mis a profit pour mettre au point un banc optique de mesure de transmission optique a l'aide de lasers. Après tests et étalonnage, nous avons utilisé ce banc pour vérifier la transmission de l'instrument FORS.

L'instrument MASCOT devrait être dupliqué pour équiper l'Observatoire de La Silla ; cette caméra pourrait être le premier pas vers un système plus complexe d'évaluation de la qualité photométrique du ciel observé par chaque UT.

12 Acknowledgements / Remerciements

I first want to thank Jean-Gabriel Cuby to have permitted me to make this training and for his confidence during all the steps of the project. Thanks also to Pedro Mardones for its good advises and to all the Instrumentation Group, Pablo Barriga, Roberto Castillo, Gordon Gillet, Nicolas Haddad, Pascal Robert, for their welcome. I also want to thank the Software Group that provided the support during the integration phase of the control software and all the personal from Paranal that have been involved in the project and gave such a good help

Many thanks also to Alain Klotz and Denis Marchais from the AudeLA development team for their efficient and pleasant assistance. And to conclude, a friendly greeting to Isabelle and Jean-Christophe.

Je tiens tout d'abord a remercier Jean-Gabriel Cuby de m'avoir permis de réaliser ce stage et pour sa confiance témoignée tout au long du déroulement de ce projet. Merci également à Pedro Mardones pour ses conseils avisés et à l'ensemble du Groupe Instrumentation, Pablo Barriga, Roberto Castillo, Gordon Gillet, Nicolas Haddad, Pascal Robert, pour leur accueil. Merci également au Groupe Software pour son support durant la phase d'intégration du programme de contrôle, et à l'ensemble du personnel du Paranal impliqué dans le projet pour leur aide.

Je tiens aussi a remercier Alain Klotz et Denis Marchais, de l'équipe de développement d'AudeLA, pour leur assistance efficace et plaisante. Et pour conclure, un salut amical à Isabelle et Jean-Christophe.

13 Bibliography

"Scientific Requirements to a VLT Observing Conditions Monitor" H.Pedersen – October 20, 1998

"VLT All Sky Imager – first ideas for implementation" H.Pedersen, M.Sarazin, A.Wicenec, C.Cavadore – June 25, 1999

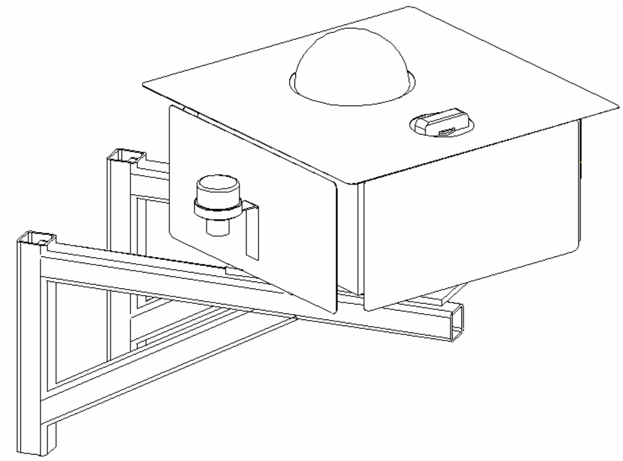
AudeLA web site: http://audela.ccdaude.com/

Audine web site: http://www.astrosurf.com/audine/

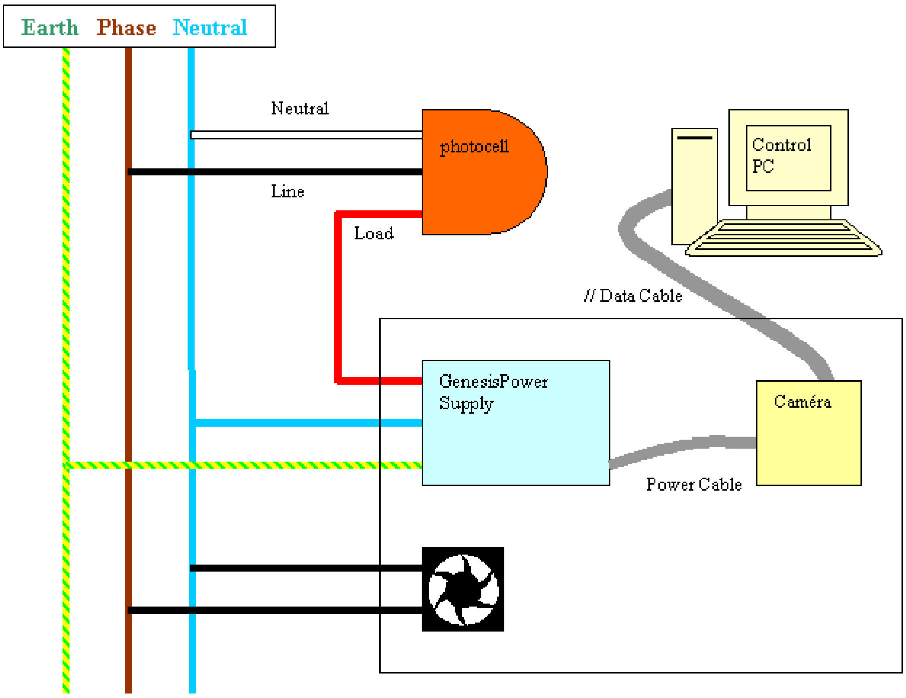
Genesis web site: http://www.genesis16.net/

14 Appendices

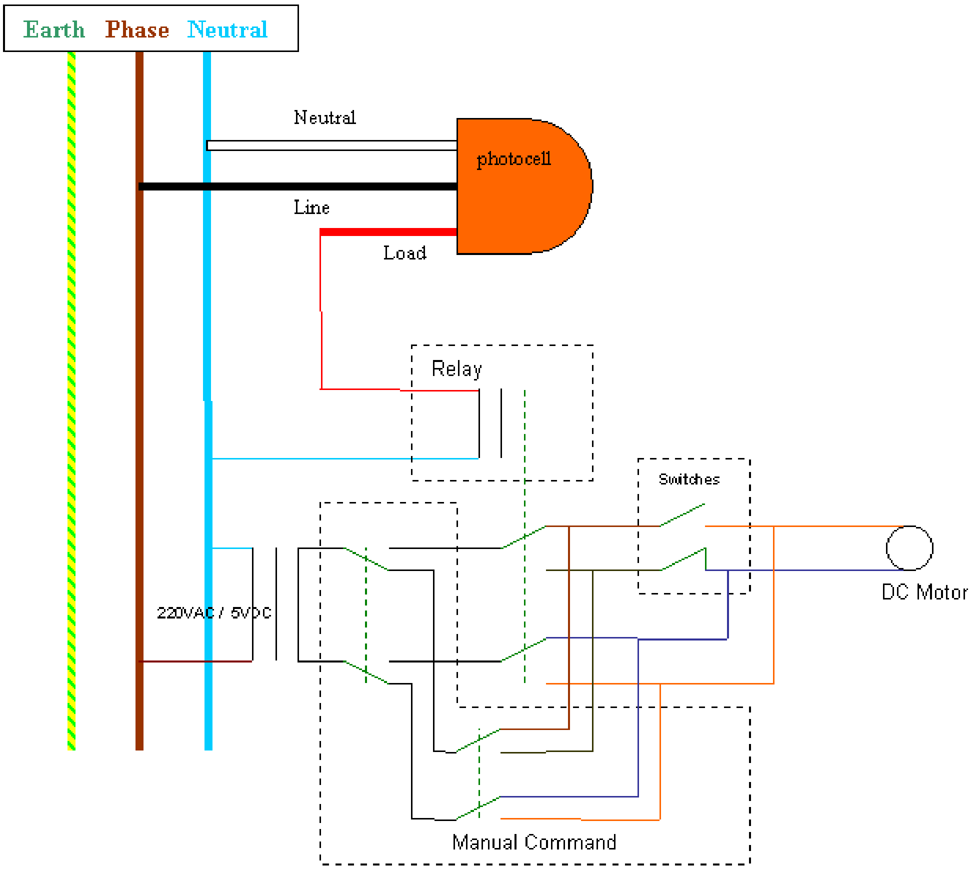
14.1 Specifications Table

MASCOT – Mini All Sky Cloud Observation Tool	
	
Camera	Genesis 16 (Audine), CCD cooled camera
CCD Type	KAF401LE (Antiblooming)
CCD Size	6.91 x 4.6mm = 512 x 768 pixels; 9um square pixels
Optics	PELCO 13VA1-3 zoom lens
Focal length / aperture	1.6-3.4mm / f1.4-closed
Field of view	180° @ 1.6mm focal length
Image	
Size	~530 pixels round image
Pixel Size	~19 arcmin/pixel
Maximum Exp. Time w. Moon	~15 sec (to avoid blooming)
Maximum Exp. Time wt. Moon	~180 sec (to avoid star trails)
Reading Time	~12 sec in binning 1x1
File Size	~750KB full frame, ~600KB resized
Software	AudeLA
Version	1.1.2 (July 2002)
Platforms	Windows, Linux
Tcl/TK version used	8.05

14.2 Electric scheme of power supply



14.3 Electric scheme of protective cap



14.4 Table of Illustrations

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