OMEGA2000 User's Manual

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With contributions from
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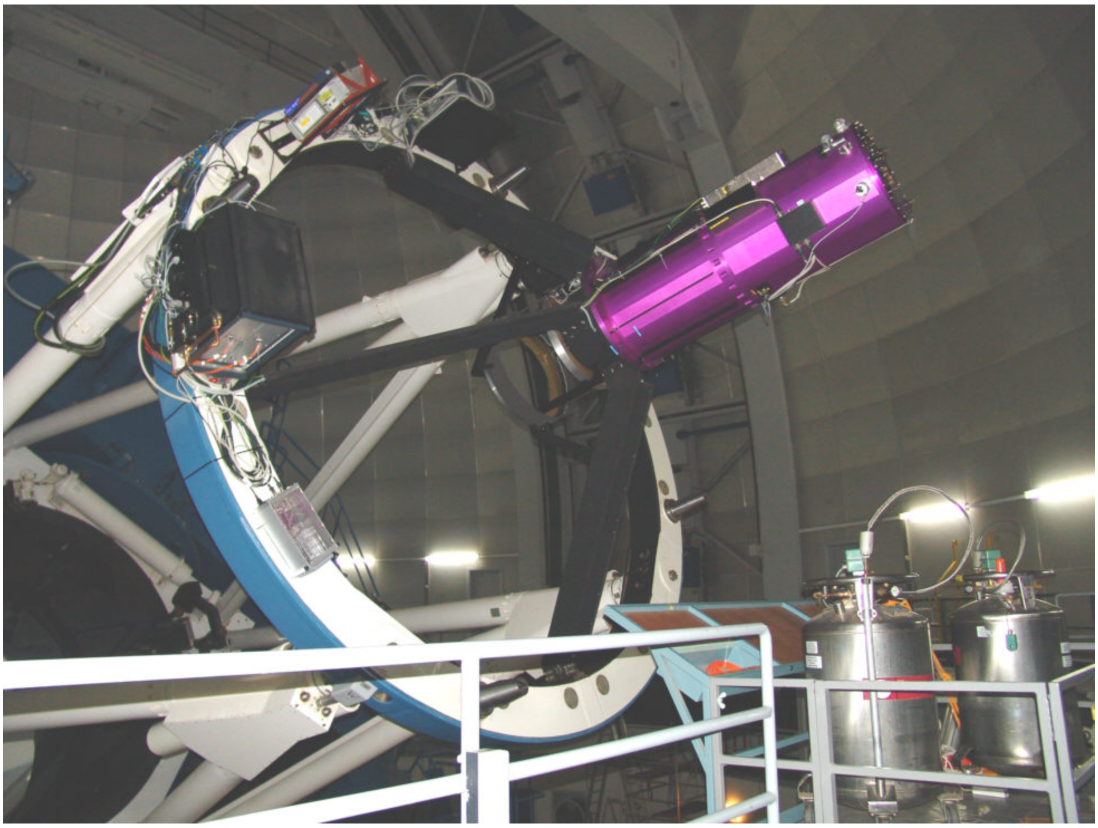
Zoltan Kovács (detector)
René Faßbender (observing macros, pipeline)

Version 2.9 (November 2008)

Parts of this manual are based on the MAGIC and OMEGA-prime user's guides.



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Appended: UKIRT faint standard stars (Dave Thompson).

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1. Introduction

Observations at infra-red wavelengths in the range between 1 and 2.5µ are in principle very similar to CCD observations in the optical wavelength range. Differences occur primarily due to the high background level in the IR (thermal background and night sky) and the different detector technology. Both have direct consequences for the observing procedures and will be described in detail in this manual. Once a raw image and its associated calibration files are obtained, the data reduction and analysis for both wavelength regimes turn out to be identical.

This manual comes in three parts. In the first part we describe IR observations and technology in general (Sections 1 – 6). The second part describes the instrument and the control software (Sections 7 – 11). Finally we give detailed instructions on how to use the OMEGA2000 camera at the telescope in Section 12. The latter contains also a description of the pipeline software available at the telescope, allowing the user to get preliminary reduced and stacked data at the telescope.

A good introduction to infrared observing and technology is given by Glass (1999). Rieke (2003; 2007) provides a detailed description of detector technology in the infrared.

2. Astronomical observations in the infra-red region

2.1. *Aim of the game*

OMEGA2000 is using one of the first HAWAII-2 detectors giving an unprecedented field of view for IR cameras of 15.4' on the sky. As such its prime application will be survey work. Due to the nature of astronomical objects this will be targeted towards the dusty, the cold and the distant universe. One should keep the survey application in mind when using OMEGA2000, because *e.g.* the observing utilities provided were written with primarily this sort of observations in mind.

2.2. *The infra-red sky*

Beyond the optical window the atmosphere becomes increasingly opaque and ground based observations are only possible in certain atmospheric windows. These are – in the Johnson system – called J, H and K for wavelengths up to 2.5 µm (see Figure 1). The major atmospheric absorbers and central wavelengths of absorption bands are H_2O (0.94, 1.13, 1.37, 1.87, 2.7, 3.2, 6.3, $\lambda > 16$ µm); CO_2 (2.0, 4.3, 15 µm); N_2O (4.5, 17 µm); CH_4 (3.3, 7.7 µm); O_3 (9.6 µm) (Cox 2000). The depth of the absorption troughs does depend on the water vapour content of the atmosphere.

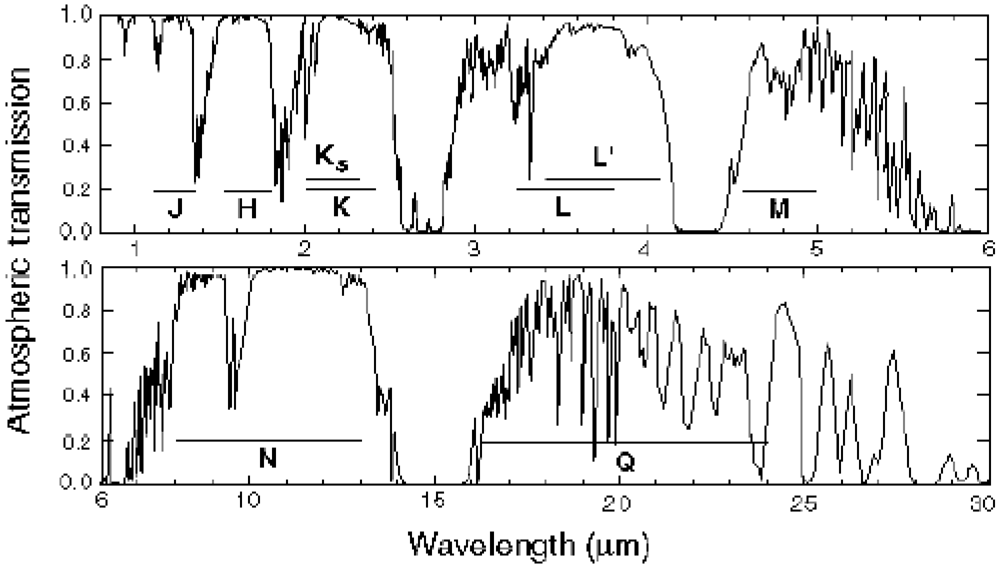


Figure 1: Atmospheric transmission as a function of wavelength in the infrared wavelength range (Cox 2000).

At wavelengths longward of 2.3 µm, thermal emission from the atmosphere and telescope produces significant background (see Figure 3). Shortward of 2.3 µm, the sky signal is dominated by airglow emission from molecules, primarily OH and O_2. This background can vary significantly, both spatially and temporally. To obtain flat sky background levels over the wide field of OMEGA2000 a careful measurement of the sky level and shape is mandatory. Sky variations constrain integration times and general observing strategy.

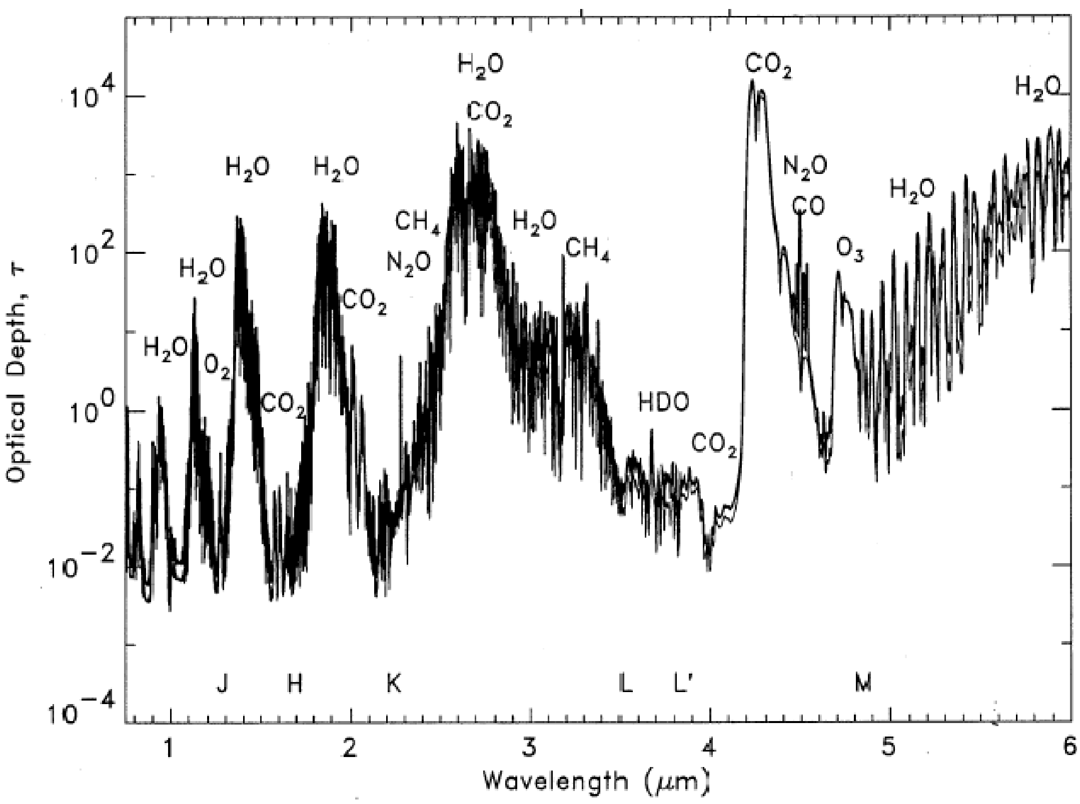


Figure 2: Contributors to the atmospheric absorption in the wavelength range 1 to 6μ 0(Cox 2000).

Figure 2 shows that water is the principal absorber at near-infrared wavelengths between 1 and 6 µm, with very strong bands centred near 1.1, 1.38, 1.88, 2.7, and beyond 6 µm. CO_2 is the next most important absorber at these wavelengths, with strong bands near 2.0, 2.7, and 4.3 µm, and much weaker absorption near 1.22, 1.4, 1.6, 4.0, 4.8, and 5.2 µm. Other trace gases including CH_4 (2.4 and 3.3 µm), O_3 (3.3, 3.57, and 4.7 µm), and N_2O (2.1, 2.2, 2.47, 2.6, 2.9, and 4.7 µm) also produce some extinction at these wavelengths.

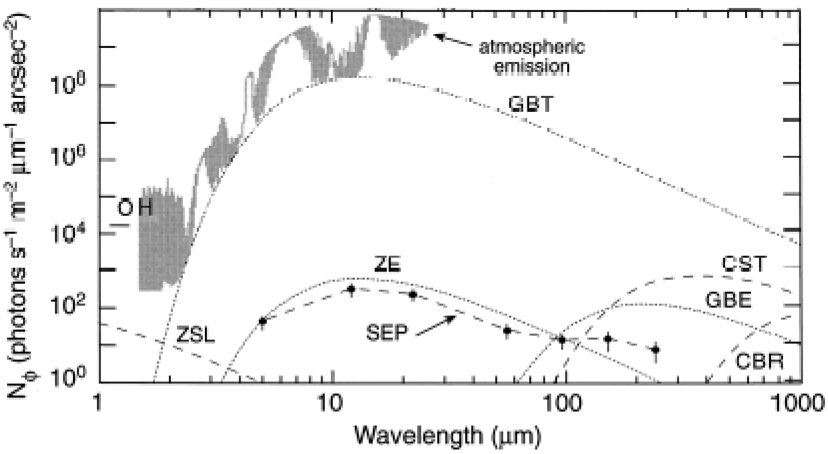


Figure 3: Background emission sources (see (Cox 2000)).

OH	OH airglow. Average OH emission of 15.6 and 13.8 mag arcsec.2 at J and H, respectively.
GBT	Ground-based telescope thermal emission, optimized for the thermal infrared and approximated as a 273 K blackbody with ε = 0.02. Emission from the Earth's atmosphere at 1.5–25 µm is shown.
ZSL	Zodiacal scattered light at the ecliptic pole, approximated as a 5 800 K blackbody with ε = 3 × 10.14.
ZE	Zodiacal emission from interplanetary dust at the ecliptic pole, approximated as a 275 K blackbody with ε = 7.1 × 10.8. Based on observations from the Infrared Astronomical Satellite (IRAS).
GBE	Galactic background emission from interstellar dust in the plane of the Galaxy. In the plane of the Galaxy away from the Galactic Centre, it can be approximated by a 17 K blackbody and ε = 10.3.

SEP South ecliptic pole emission as measured by the Cosmic Background Explorer (COBE) spacecraft.
CST Cryogenic space telescope, cooled to 10 K with ε = 0.05.
CBR Cosmic background radiation, 2.73 K blackbody with ε = 1.0.

The dominant source of sky background emission in the wavelength range concerned by OMEGA2000 is the OH emission, often expressed in units of Rayleighs:

$$\begin{aligned} 1 \text{ Rayleigh unit} &= 10^{10} / 4\pi \text{ photons / s / m}^2 \text{ / sr} \\ &= 1.5808 \times 10^{-10} / \lambda_{\mu m} \text{ W /m}^2 \text{ /sr} \end{aligned}$$

$$1 \text{ Rayleigh / Å} = 0.1870423 \text{ phot / m}^2 \text{ / s / nm / □''}$$

A detailed calibrated OH-emission spectrum is published by Maihara (1993), Ramsay (1992), a high-resolution spectrum by Rousselot (2000). For a complete overview of the nightsky background see Leinert (1998).

In narrow-band imaging the level of the night sky does depend critically on the exact pass band. Therefore no empirical values for OMEGA2000 can be given yet. For the broad band filters the following table gives the approximate levels to be expected (to be updated):

J	80 R/Å
H	260 R/Å
K	430 R/Å

Table 1: Background levels in the most common observing bands.

3. Detecting photons

3.1. *Focal plane arrays for the infra-red*

Infrared focal plane arrays (FPA) differ from visible wavelength CCDs in requiring special semiconductors with a smaller energy difference between the valence and conduction bands. Typical materials include indium antimonide (InSb), platinum silicide (PtSi), and mercury cadmium telluride (HgCdTe). OMEGA2000's detector is a HgCdTe device. The figure below contains a schematic drawing of the Rockwell NICMOS3 infrared array in OMEGA2000.

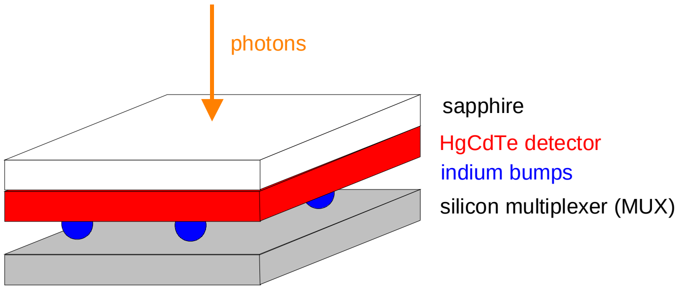


Figure 4:Schematic structure of a HgCdTe HAWAII2 detector

Photoelectrons are collected in the detector material and read out using a multiplexer. Because silicon multiplexer technology is much more mature, HgCdTe and InSb arrays are *hybridized*. This means that the detector material is cold welded to a silicon multiplexer using a series of small indium bumps. The actual HgCdTe detector material is grown on a sapphire substrate for mechanical strength. This hybrid arrangement has the benefit of lower crosstalk and less blooming and streaking compared with visible wavelength CCD's. Another significant advantage of the hybrid is that it permits *non-destructive readouts* of the detector, in which the voltage on the pixels can be measured without affecting charge collection.

During the detector reset a constant voltage is applied to all pixels. Incoming photons deliberating charge in the detector substrate reduce this voltage. Saturation occurs if the voltage has been completely reduced by the photons. This process of signal detection / storage is the major difference to a CCD, where charge is collected in a pixel, leading to smear-out effects in case of saturation. The following figure from the PhD thesis of Martin G. Beckett (1995) gives a vivid discrimination between a CCD and an IR FPA:

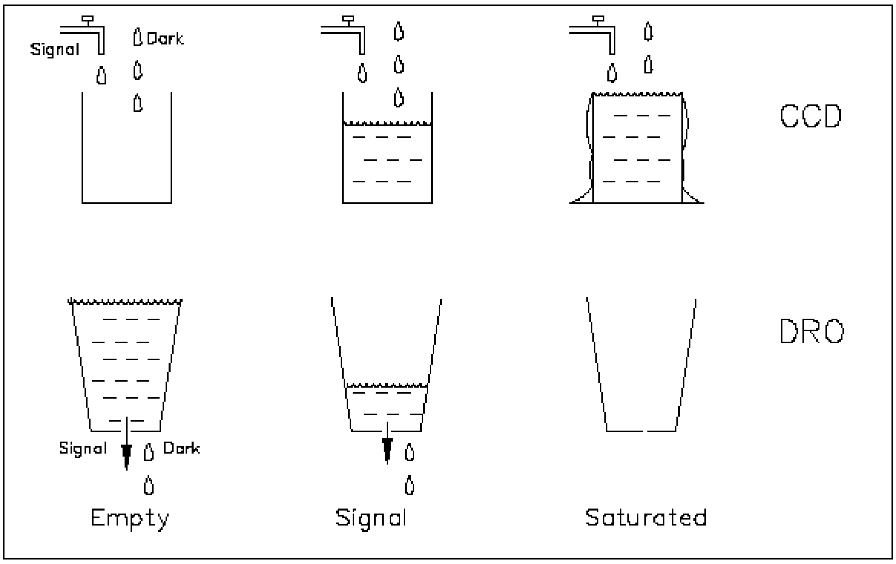


Figure 5: Difference of detector saturation between a CCD and an infrared detector.

3.2. *Read-out techniques in general*

The figures below are a schematic representation of the voltage on an individual pixel as a function of time. At the beginning of an exposure the voltage is set to a predetermined value by a *reset*. When the reset switch is opened, the voltage will jump to a variable new level[1] (the *pedestal*) and then increases linearly with time as charge from photoelectrons and dark current accumulates in the detector. This process continues until the detector is reset to the original level at the end of the integration. The linear behaviour of most modern detectors spans the range from zero charge to over 90% of the total capacity.

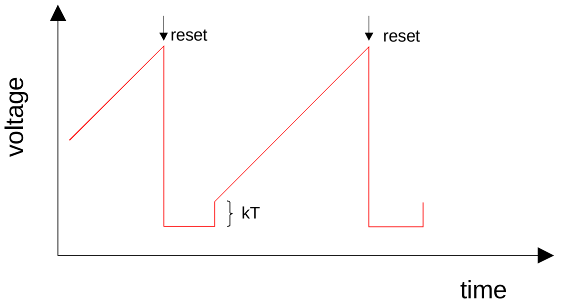


Figure 6: Detector readout: voltage as a function of time

OMEGA2000 supports a number of detector readout modes suitable for various observing situations. These modes appear under the <Readout> menu and can be invoked with the **ctype** instruction from the command line interface and from macro files. Their detailed properties beyond the general principles described here will be presented in Section 7.1.1.

3.2.1. Reset-read

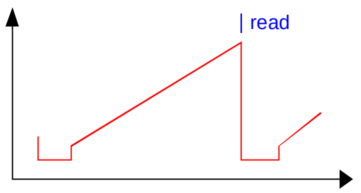


Figure 7: Read-out mode "reset-read"

This is the simplest readout scheme. The pixels are reset and read out once at the end of the integration. This does not remove the variable pedestal level (kTC noise) and any initial offsets which can vary from pixel to pixel. We do not recommend using this mode for observation. Its main usefulness is in checking the signal level for saturation.

3.2.2. Reset-read-read (double correlated read)

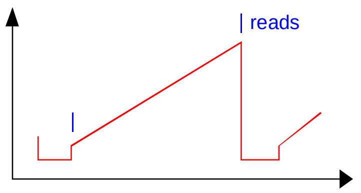


Figure 8: Read-out mode "Double correlated read".

Also known as Double-Correlated Sampling, this is the most commonly used mode for general observing. The array is read immediately after the initial reset and before the final reset at the end of the integration. This eliminates the kTC noise and other offsets, but increases the read noise by $\sqrt{2}$ because the noise from two readouts goes into a single image. We recom-

[1] The variability is caused by a quantum noise source called kTC noise, the thermally induced fluctuations of voltage on a capacitance C at temperature T.

mend this readout mode, particularly for broadband imaging where you reach the background limit quickly (and can thus accept the higher read noise).

3.2.3. Multiple end point sampling

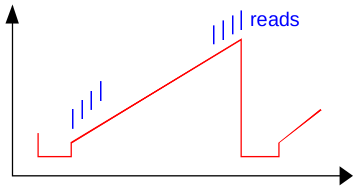


Figure 9: Read-out mode "multiple end point sampling"

This mode is not implemented in OMEGA2000!

This variant of Double-Correlated Sampling is also known as Fowler sampling (see (Fowler and Gatley 1991)). The array is read multiple times after the initial reset and before the final reset. This scheme can reduce the read noise substantially, theoretically by a factor $\sqrt{N}$. In practice, however, amplifier glow and other effects limit the. This mode is recommended in low background applications.

3.2.4. Sample up the ramp

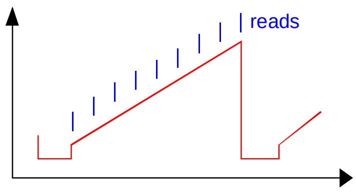


Figure 10: Readout mode "sample up the ramp"

This mode is not implemented in OMEGA2000!

This readout scheme also reduces the effective read noise, since the pixel voltage is sampled N times at equal intervals during the integration. The total signal comes from a linear fit through the measurements (ctype ramp) or from saving the differences between adjacent reads (ctype speckle). The latter is used for speckle interferometry since the observer can save these adjacent differences as separate frames, each of which is a rapid exposure on the sky. Warning: Be careful not to saturate the **total** signal in this mode. This can happen easily when observing lunar occultations, for example. You may have to settle for a shorter sequence.

More details about the read-out modes are given in the PhD thesis of Zoltan Kovács (2006).

4. Sources of noise, signal-to-noise ratio and exposure times

When planning observations the basic task is to estimate the integration time necessary to achieve the required signal-to-noise ratio (S/N). The following sources contribute to the noise:

- Sky background *S* [counts/pixel/sec]
- Dark current *D* [counts/pixel/sec]
- Read-out noise *R* [electrons/pixel/read]
- Object flux *F* [counts/sec]

The S/N achieved for an object of flux *F* [counts/sec] spread out over a circle of radius *r* on the detector [pixel] after an integration time of Δt seconds is then

$$\frac{S}{N} = \frac{F \times \Delta t \times EPC}{\sqrt{(F + (S + D) \times \pi r^2) \times EPC \times \Delta t + \pi r^2 \times R^2}}$$

Here *EPC* is the conversion factor electrons-per-count.

The integration time should as a minimum be so long that the denominator in the above formula is no longer dominated by the read-out noise. Ignoring object flux and dark this requires

$$\Delta t \geq \frac{R^2}{S \times EPC}.$$

Due to the variability of the night sky, this integration time should also roughly determine an upper limit to the integration time. Optimisation between adequately sampling the brightness variations in the sky background, avoiding to be detector limited and keeping the number of data files at a manageable level is the primary objective in planning infrared observations.

The S/N at short integration times (*i.e.* in the detector limited range, where the noise is dominated by the read-out noise) is proportional to Δt. In the background limited regime S/N increases only with the square-root of the integration time.

If the measuring aperture is adjusted to the seeing, then for stellar images in the background limited case the exposure time increases with the seeing squared if aiming at a constant S/N:

$$\Delta t \propto \left(\frac{S}{N}\right)^2 \frac{S \times r^2}{F^2}$$

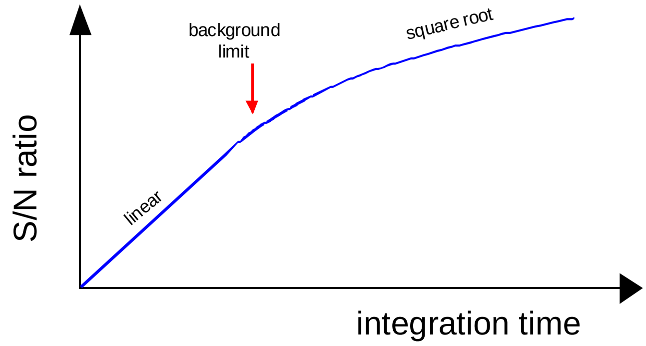


Figure 11: Signal-to-noise ratio as a function of integration time.

For narrow-band imaging a detailed knowledge of the exact filter transmission and the location and strengths of OH-emission lines within the filter range is mandatory.

5. Imaging strategies

With OMEGA2000 the standard observing goal is to survey a large area on the sky in one or more filters. For this type of observations the main challenges are field coverage and background subtraction.

5.1. *Mosaicing a field*

Covering a large area on the sky with a detector of limited field of view (FOV) poses two problems: Image distortion due to imperfect optics and field rotation due to the telescope mounting, in our case the parallactic mount of the 3.5m-telescope.

For OMEGA2000 the quality of the optics is excellent, with a centre-to-corner distortion of 0.12"only[2]. Furthermore no chromatic effects are measurable. Field rotation is unavoidable: Assume two objects with same RA are located on the central detector column in one image. Then the vector connecting these two objects will be inclined in the adjacent image offset by $\Delta\alpha / \cos(\delta)$ by an angle $\Delta\phi$. This is illustrated in Figure 12 at right. The rotation angle is

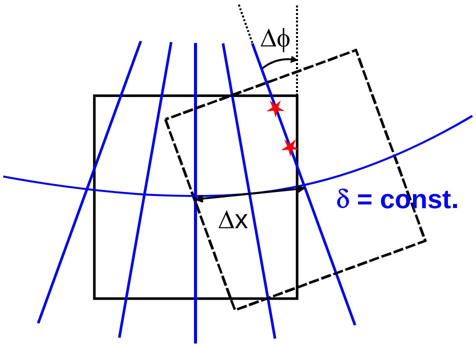


Figure 12: Field orientation in a mosaic of images taken with a parallactic mount of the telescope.

$$\Delta\phi = \Delta x \tan(\delta) .$$

In case of OMEGA2000 this rotation will result in a misalignment of objects in two adjacent mosaic images. If a stellar image at the border of the detector in X and in the centre in Y is assumed to be aligned in the two adjacent mosaic images an object in the upper/lower corner would be misaligned by

$$\Delta p = \pm 0.5 \times 2048 \times \tan \Delta\phi = \pm 1024 \times \tan(15.4' \times \tan \delta) \text{ pixels} .$$

The following table provides the Δp values as a function of declination:

declination δ	0°	10°	20°	30°	40°	50°	60°	70°	80°
$\pm\Delta p$ [pixels]	0	.8	1.7	2.6	3.8	5.5	7.9	12.6	26.0

Table 2: Image rotation as a function of declination.

A differential effect in the same sense will also be created by dithering images (see below)!

5.2. *Background subtraction*

Traditionally the classical photometry consisted of measurements of the source in one aperture and the neighbouring sky in another. Then object and sky switched apertures and the procedure repeated. With an FPA the sky still needs to be determined with sufficient accuracy to

[2] This is the difference between the angular distance of an object in the corner to an object in the centre calculated from the RA and DEC coordinates using spherical trigonometry and the distance between these two objects calculated from the X and Y coordinates on the detector, using a constant pixel scale.

enable extraction of the pure source signal. But the situation is different as we automatically get neighbouring sky "for free" in our images. Only in case of very extended objects filling a good fraction of the FOV do we still need to take separate sky exposures.

The technique to determine the sky from the science frames themselves is called dithering[3]: Between science exposures of the same field, the telescope is offset by small amounts bringing the objects to slightly different places on the detector. This allows a given pixel to see pure sky in most of the images. In the example at right pixel A sees pure sky in frames 1 to 4, pixel B only in frames 1 and 2. Stacking images via a median-like process eliminates object signals and cosmic ray events. The result is a frame with pure sky only. There are two caveats, however. As mentioned above, offsetting the telescope introduces a field rotation. Thus in dithered images the images cannot be aligned perfectly. The effect for low declination and small dithering offsets is small, however.

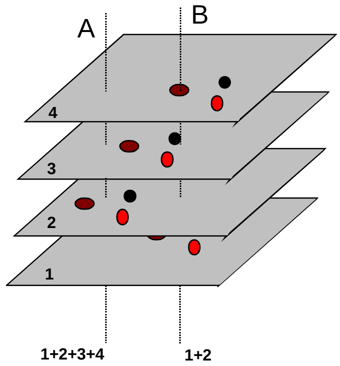


Figure 13: Determination of sky background from dithered science frames.

Furthermore, the sky illumination is changing, both in level and in shape (Faßbender 2003). Therefore a consistent sky image can only be extracted from the science frames taken shortly before and after a given image. From these the contemporary sky frame is extracted by a median-like procedure and this is then subtracted from this particular science frame (see Section 14 for details). This procedure has to be taken into account planning observations.

For extended sources dithering this way is not appropriate as no pixel will see pure sky in most of the images. Therefore additional observing time has to be included to measure the sky level by offsetting the telescope by amounts large enough to bring the target out of the FOV. Variations in the shape of the night sky emission cannot be removed this way, however. In order not to loose too much telescope time with sky observations (whose S/N per pixel should be larger than the object frame, in order to preserve the S/N of the science frame during sky subtraction) one should smooth the extracted sky frame (see Sections 6.17 and 6.18 for details).

[3] In the MAGIC manual this is called the „moving sky" technique.

6. Image calibration

6.1. *Focussing the telescope onto the detector*

The optimum telescope focus changes mainly with temperature of the telescope structure. For the 3.5m-telescope this change is –165 μ/°C. A smaller effect is introduced by flexure of the telescope mount. Once an initial optimum focus is found the automatic focus compensation by the telescope computer takes care of most of these changes during the night. So the main task is finding an initial good focus. This is accomplished by a focus test series, during which the telescope focus position is systematically varied and the width of stellar images is measured for each of the focus settings. Whereas with CCDs the whole series can be stored on a single frame with the charge shifted between the individual focus settings, with infra-red detectors individual frames have to be taken for each focus setting due to the high background, which requires short integrations.

We provide suitable focus fields (Appendix 7) and supply a procedure to take a focus series, analyse the width of the stellar images as a function of focus value, and set the best telescope focus (see Section 13.1).

6.2. *Flat fielding*

Each pixel of a FPA has a slightly different quantum efficiency than its neighbours. Furthermore there are larger scale variations of the quantum efficiency across the detector. To complicate matters further, the quantum efficiency is a function of the wavelength of the incident radiation. Thus flatfields need to be taken for all filters in use during the observing campaign! Vignetting due to the optics and dusk on optical elements produce effects which are similar to the variations in quantum efficiency: Illuminating the detector homogenously will not produce a constant signal on the FPA. Flat fielding is the process to correct for all these effects and produce flat images if the illumination would be homogenous. Turning the argument around, a flat field image is a homogenously illuminated frame which can be used to correct the measured signal by dividing the images by such a normalized flat field frame. As every science frame is divided by this flatfield image care has to be taken not to reduce the S/N of the science frames by “underexposed” flatfields. One has to make sure that the S/N of the flatfield images is much higher than that in the science frames (including object signal!) in order to preserve their S/N.

The effects just described are multiplicative effects, *i.e.* they change the counts above background from the objects to be measured. There are also, however, additive flat field effects which also produce non-flat images but do not change the signal from the objects under study: Scattered light within the optics and fringing due to night-sky emission lines are the two most important examples for additive flat field effects. In practice it is often difficult to disentangle additive and multiplicative flat field effects and the inability to do this often limits the photometric accuracy achievable.

The optimum way to get at least a global multiplicative flatfield is to observe a star during photometric conditions placed on the detector at regular intervals, *e.g.* every 30" in both X and Y. As this procedure is certainly not practicable during regular observing runs we plan to provide such flatfields for the most commonly used filters during the commissioning phase. Then the flatfields taken by the observer during the run are only need to correct only the pixel-to-pixel sensitivity variations and changes in vignetting due *e.g.* moving dust specks.

The central issue in flatfielding nevertheless is to illuminate the detector in a homogeneous way. Creating such a homogenous illumination is not trivial. Several types of flat fields are commonly in use:

6.2.1. Sky flats

The twilight sky is often used in CCD-astronomy to take flatfield images. In principle, this is also possible in the near-infrared range. But depending on sky conditions and the field of view of the detector, the sky brightness might vary across the FOV prohibiting a good flatfield image. Currently we have no direct experience in this respect with OMEGA2000. The same is true for the median filtered science exposures, which are devoid of object signal if the images were dithered. However, again here variations in sky background and S/N considerations are a major obstacle using these data as flatfields. One can, however, hope that if sufficiently many science frames are averaged the sky variations are averaging out. A procedure to take twilight flats is described in Section 13.3.

6.2.2. Dome flats

Homogenous illumination of a flatfield screen in the dome eliminates the above mentioned shortcomings. However, the homogenous illumination of the screen is not easy and often the flatfield lamps are too bright. Due to the dome geometry it is also sometimes difficult to not illuminate parts of the telescope structure, which should be avoided to prohibit scattering light into the light path. A big advantage of domeflats is that one can use the amble time in the afternoon to take the flats. Thus S/N is normally not an issue. To eliminate the thermal emission of the screen and dome surroundings one has to take flatfields in pairs with lamp on and lamp off. The actual flatfield is then the difference image (lamp on – lamp off). This at the same time eliminates any dark count signal from the detector. A procedure to take well illuminated dome flats is described in Section 13.2.

6.3. *Dark current*

Even if covered by a cold aluminium blank in the filter wheel, pixels may show a time dependent signal, the dark current. Most pixel are well behaved in that their dark current is negligible or scales with exposure time. Fore these the dark current can be modelled and subtracted. We provide two files which give constant and slope of a linear fit to the dark signal as a function of time to correct for this (see Section 13.10 on page 73 for a MIDAS utility to create these files from a series of dark exposures). Again care has to be taken not to destroy the S/N of the science frames by a bad dark frame with insufficient S/N.

All pixels not following a linear relation between exposure time and dark signal are treated as bad pixels and are represented in the bad pixel mask.

6.4. *Bad pixel mask*

Dead pixels or pixels with an uncorrectable dark current (hot pixels) have to be interpolated from the neighbouring good pixels. To facilitate this we provide a bad pixel mask, whose pixel values of 0 indicate good, those of 1 bad pixels. The mask was derived from the dark current analysis by an appropriate cut in the goodness-of-fit of the linear relation between dark current and exposure time. The same was done for a series of dome flats. Both series were analyzed with the MIDAS procedure `bias/extrapolation` described on page 73.

6.5. *Linearity*

Exposing a detector pixel to twice the number of photons should result in an exactly duplicated recorded signal. This is, however, not strictly true in general. Each pixel may behave slightly non-linear.

We have measured the linearity of FPA #77. Using the thermal emission of the front cover and controlling the exposure level via the exact exposure time we have fitted the signal as a function of exposure time for each pixel with a parabola (see MIDAS procedure `bias/extrapolation` on page 73). For each coefficient we have created an image, whose pixel value specifies the coefficient for this pixel. Using these frames, any non-linearity can be investigated. Details are given in Appendix 3.

We have not yet done this for different filters. Thus we cannot comment on an wavelength dependence of the linearity / non-linearity.

6.6. *Astrometric calibration*

The image scale in arcsec/pixel and the image distortion of the camera has been measured during the commissioning runs (see Section 7.2). These should remain fixed for the future. However, the orientation of the detector's Y-axis may change slightly when the instrument was dismounted or especially if for any reasons the detector had to be removed. To easily check the astrometric properties we supply a list of astrometric fields with a sufficient number of astrometric reference stars from the M2000 catalogue (Rapaport, Le Campion et al. 2001). These are listed in Appendix 8, where finding charts marking the stars from the M2000 catalogue as well as copies from the DSS are provided. Elevation charts facilitate selection of a suitable field throughout the year. Tables of these stars as well as a subset with proper motions from the UCAC2 catalogue are provided on fire35 as html files in the MANUAL path.

Pixel scale is (0.447312 ± 0.000003)"/pixel in the Ks filter (no blocking filter used).

Please note: Due to the additional blocking filter needed for some filters the image scale is changed for these filters by approximately 2.5 / 1000.

More information may be found in the Diploma thesis of Anke Kitzing (2006).

6.7. *Photometric calibration*

For a rough photometric calibration we provide the expected counts in all the filters for a 0^{th} magnitude star in Appendix 9. For a more accurate calibration photometric standard stars of known broad-band magnitude are needed and we reproduce the standard lists from the literature and other observatories in Appendix 10. For narrow-band imaging the calibration via these stars may be problematic depending on the accurate spectral run within the bandpass. For these synthetic photometry may be more appropriate and we hope to supply the relevant data in the near future.

The 2MASS catalogue provides magnitudes in *J*, *H* and *Ks*. Due to the large field of view there will always be stars from this catalogue in the field for calibration. The 2MASS catalogue may be accessed via the web page

http://www.ipac.caltech.edu/2mass/releases/allsky/index.html .

7. OMEGA2000

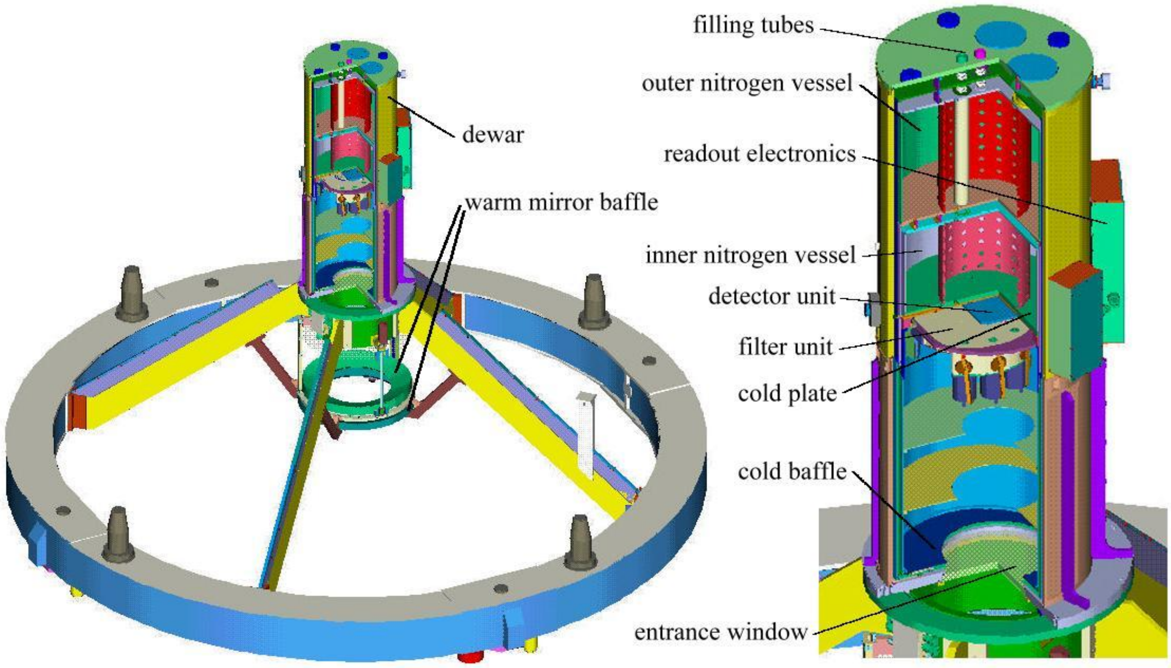


Figure 14: OMEGA2000 on the frontring (cut-away CAD draing).

7.1. *Detector*

The OMEGA2000 camera contains a focal plane array (FPA #77) of type HAWAII-2 by Rockwell with 2048 x 2048 pixels, each 18 μ wide. It is sensitive from about 850 to 2500 nm. We provide in Figure 15 a measurement from ESO (red) together with the actually measured values in the three broad-band filter *J*, *H*, *K* fo our detector (blue). A histogram of pixel values in a supposedly homogeneously illuminated image is show at right where the median pixel value is at about 250. The corresponding two-dimensional sensitivity map is given below. We summarize the main detector characteristics in Appendix 3.

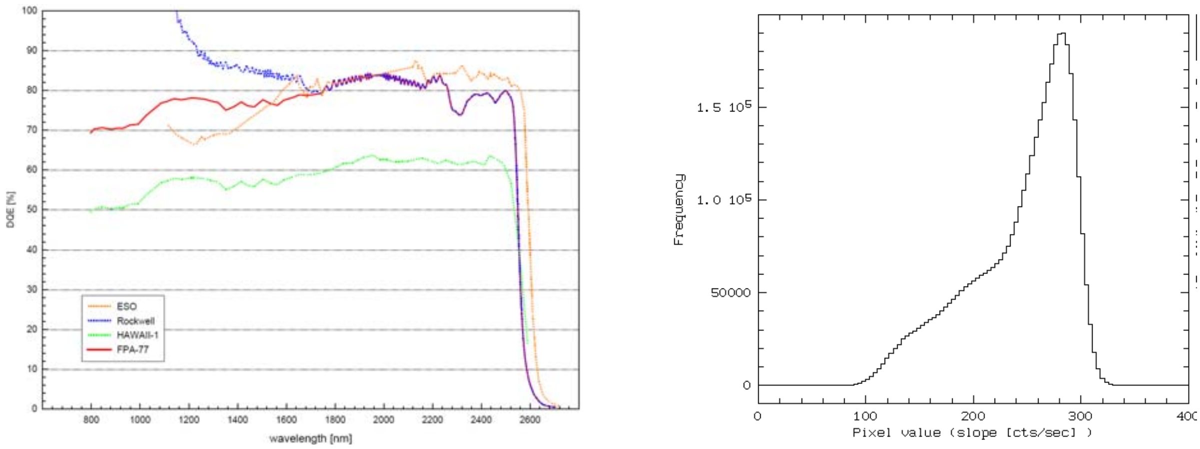


Figure 15: Quantum efficiency of a HAWAII-2 detector as a function of wavelength (left). The ESO-data are from a different detector (Finger 2002), the Rockwell data are from a detector dotted similarly to FPA-77, which unfortunately was not measured. The adopted DQE-curve for FPA-77 is shown in red.

Histogram of quantum efficiency across the detector for FPA #37 (right).

The read-out noise for a double-correlated read (*i.e.* two reads for a single image) is 17 e^-. The detector is clocked with a rate of 320 kHz, resulting in a minimum integration time of

$$\frac{2048\times 2048\ \text{pixels}}{32\ \text{channels}} * \frac{2\ \text{images}}{320\ \text{kHz}} = 0.80\ \text{sec}\,.$$

The conversion factor from counts to electrons (EPC [electrons per count]) has been determined for all 32 channels separately. The average is 4.42 ± 0.06 for FPA 48 (“Lucifer” detector used in 2003) and 4.87 ± 0.05 for FPA77, the detector in use since April 2004. Details can be found in the PhD thesis of Zoltan Kovács (2006).

The channel layout is show in Figure 16. Channels are numbered along the fast direction, starting with quadrant I. For more details on the detector see Appendix 3.

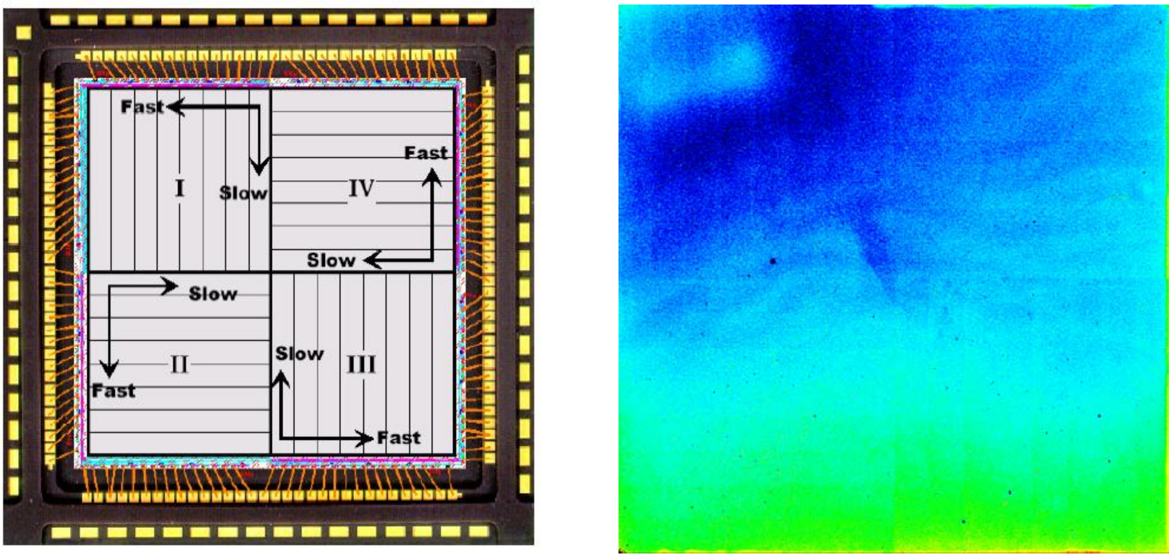


Figure 16: Quadrant and channel layout for the HAWAII-2 detector (left) and H-band twilight flat (right). The cut values for the flat are 130 (black) to 340 (red).

7.1.1. Read-out modi implemented for OMEGA2000

This description of the read-out modi is taken from the PhD thesis of Zoltán Kovács (2006).

There are three output modes available for the chip, which can be controlled via the readout patterns. In the *Single Output Mode* all data is routed through only one channel per quadrant. If the chip is set to *Eight Output, Unshuffle Mode* the data is spread across all the output channels of the detector, namely eight per quadrant. Each output provides data from 128 consecutive columns. The *Eight Output, Shuffled Mode* is similar to the previous one, except the data from each block of 128 columns is cyclically shifted to the next output bus. In normal operation of OMEGA2000 the *Eight Output, Unshuffled mode* is preferred because of its high speed.

The background limit will be reached in broad-band imaging with HAWAII-2 array on OMEGA2000 in a few seconds. Series of images are therefore required to achieve sufficient S/R, so it is very important that the array can be read out as with the minimum dead time. The minimal integration time is given by the frame readout time and for all readout modes it is order of one second. All the modes can be characterized with their efficiency, that is the ratio of integration time to a total cycle time required to obtain an image. There are several readout modes feasible for OMEGA2000 but some of them are used only for engineering function.

Reset Level Read

The readout of the reset level of the full array has the simplest readout scheme: first the complete frame is reset then read out. A line reset is implemented for HAWAII-2 FPA, which means that one reset pulse always resets a complete line of pixels and the chip needs 1024 pulses to reset the full frame while clocking through the horizontal shift register. It allows to accomplish the reset-readout cycle in two ways: either the readout process is preceded by re-setting of the complete frame or the whole array is reset and read out simultaneously. In the first case the elapsed time between resetting and reading out of the same pixel is equal to the resetting time of the full array. The reset-readout scheme is faster in the second case, where each row is read out immediately after being reset (Figure 17). As the video signal sampled after resetting contains the reset noise and reset bias this readout mode has only engineering purpose and is normally not available for observation.

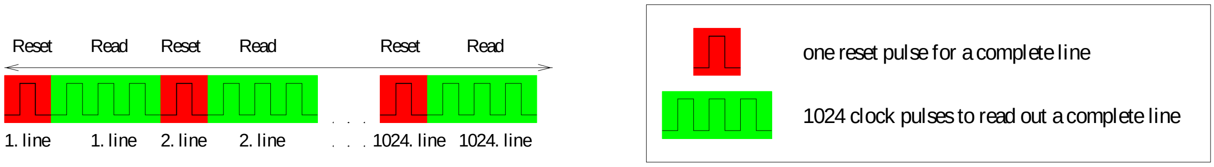


Figure 17: The scheme of the reset level read (reset-read).

Non-correlated Sampling or Single Correlated Read

In the normal operation of the image sensor an integration time should elapse between the reset and the readout of the full frame so that some amount of photo signal could be collected. The readout cycle of non-correlated sampling implements this reset-integration-read scheme (Figure 18). Now the resetting is separated from the readout process by integration, which prevents the application of the fast reset method. Since the exposure takes from the resetting of the first pixel (actually the first line) to the readout of it, the resetting time of the full frame should be added to the integration time so as to obtain the total exposure time. The integrated frame contains not only the signal collected during exposure but also the reset bias and noise as in the previous mode, therefore this readout scheme is also suggested only for engineering function.

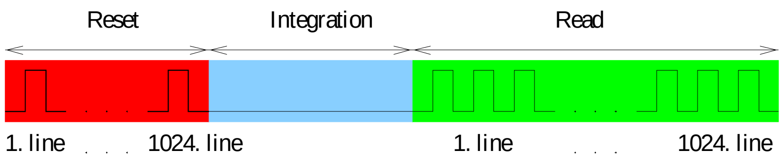


Figure 18: The scheme of non-correlated sampling (reset-read).

Correlated Double Sampling or Double Correlated Read

The scheme of Correlated Double Sampling (CDS) consists of a complete frame reset, a read-out of the full array, an integration and a readout of the complete integrated frame. The reset and the first readout of the frame are not simultaneous, *i.e.*, a slow reset is applied (Figure 19). The output signal is obtained by the subtraction of the reset frame from the integrated one, which eliminates the reset noise and bias from the signal value. Since the whole array must be clocked three times (one full frame reset and two readouts of the full frame) the efficiency of this readout scheme is only 33% at the minimum integration time. Nevertheless, it allows to check linearity of the detector and to create a bad pixel map of it. If we apply long integration time without IR illumination of the array then a dark current map can also be created.

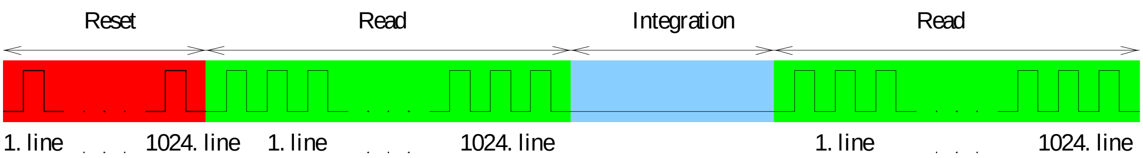


Figure 19: The scheme of correlated double sampling (reset-read-read).

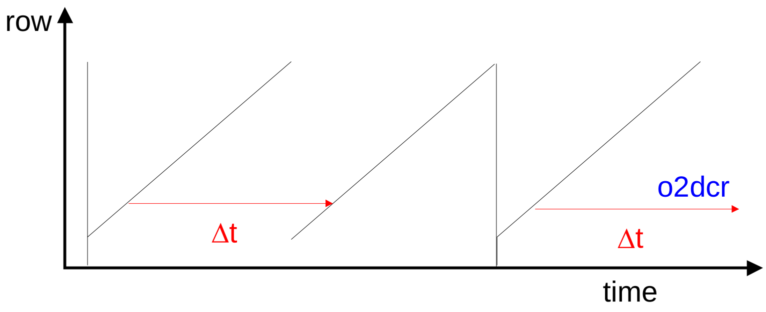


Figure 20: Alternate representation of the double correlated read.

Correlated Double Sampling with Fast Reset

The correlated double sampling can also be implemented with the fast reset scheme. This means that the reset and the readout of the reset level are carried out simultaneously and followed by the integration and the readout of the integrated video signal (Figure 21). The result frame is provided by subtraction of the reset level from the integrated signal. Since the whole array is clocked only two times, once for the reset with the first readout and once for the second readout, the efficiency of this readout scheme is 50% for the minimal integration time. The CDS with fast reset is planned to be one of the optional readout modes for scientific operation.

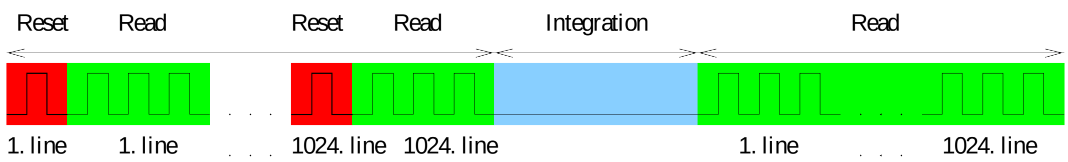


Figure 21: The scheme of correlated double sampling with fast reset (reset-read-read).

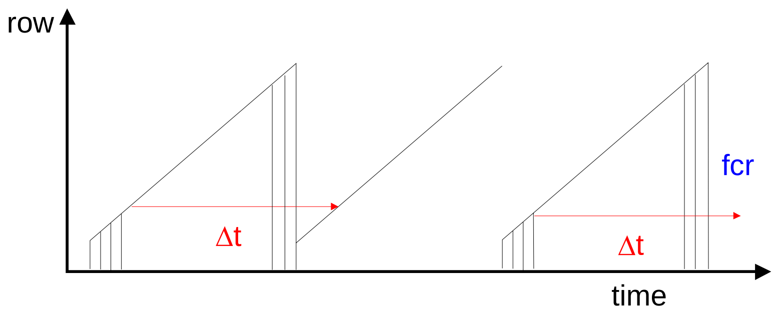


Figure 22: Alternate representation of the double correlated read with fast reset.

Line interlaced Read

It is possible to extend the CDS with fast reset in such a way that the readout of the integrated signal in each line is followed by a line reset and a readout of the reset values in that line. As a result, a complete frame is reset and its reset level is read out for the next cycle while the array is clocked line by line to obtain the integrated signal in the actual cycle. This method of interlacing the neighbouring readout cycles of lines is the most effective solution for CDS because each line is reset and the bias values are read immediately after reading the integrated pixel values (Figure 23). The CDS with fast reset waits until the video signals in the whole array have been read before resetting the unit cells in the next cycle. To obtain just a single image the CDS with fast reset takes the same time as the line interlaced mode, but for a sequence of many repeats, the latter is much quicker. Perhaps the technique of the line interlaced read can guarantee the most stable operation of the image sensor because each line in the frame is read out twice before and after the integration. As it can be seen, all the lines of pixels in the adjacent readout cycles are interlaced in contrast to the previous modes, where each readout cycle carries out a complete readout process. This readout mode is also available for scientific purpose.

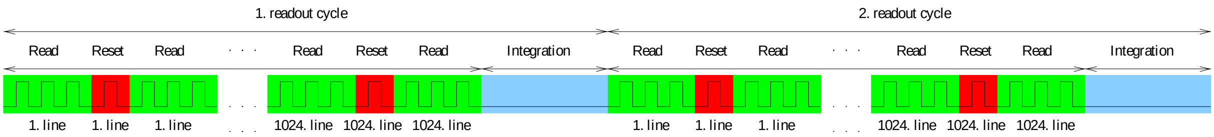


Figure 23: The scheme of the line interlaced read.

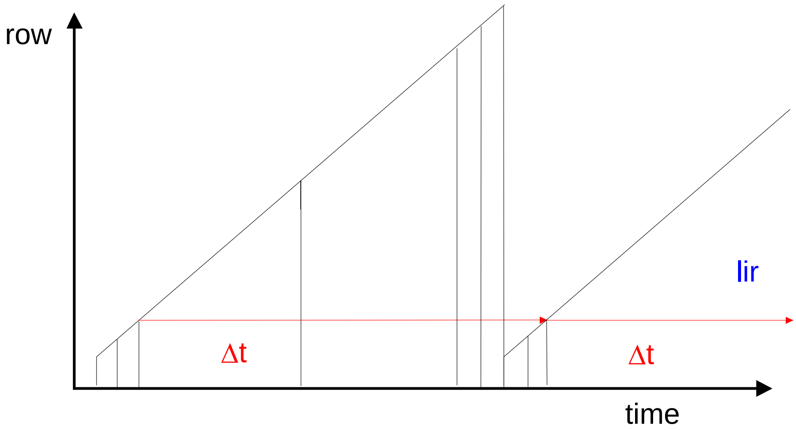


Figure 24: Alternate representation of the line interlaced read.

Multiple End-point Read

This read out mode is similar to the double correlated read but here the readout cycle contains 2 x *n* readouts instead of two. After the complete frame reset the full array is read out *n* times and the average of the *n* frames provide the bias values of the pixels after reset. After the integration the complete array is read out *n* times again and the average of these frames is taken as the integrated signal (Figure 25). The video signal is the difference of the two averaged frames. Although this readout mode allows a stable operation the duration of one readout cycle is in order of seconds even if a fast reset is implemented, which may cause the minimal integration time to be too long.

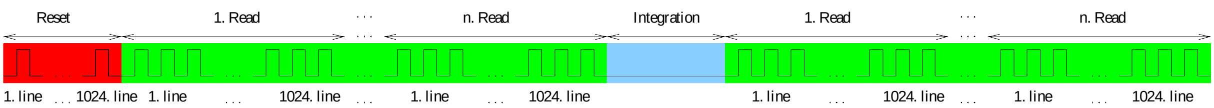


Figure 25: The scheme of the multiple end-point read.

The single pixel read

The read out cycle starts a full frame reset (line by line) then only one pixel is read out per channel or quadrant according to the *Four* or *Eight Output Mode*. Thus the data of a full channel or a quadrant consists of the value of only one arbitrarily chosen pixel. This mode is only for engineering purpose.

7.2. *Optics*

The optics, consisting of 4 lenses made of CaF_2, fused silica (FS), BaF_2, and ZnSe, is achromatic between 850 and 2500nm. The centre to corner image distortion is almost negligible, 0.12" over a distance of more than 600". The image scale is 0.44962 "/pixel in H (see also diploma thesis of Anke Kitzing (MPIA)).

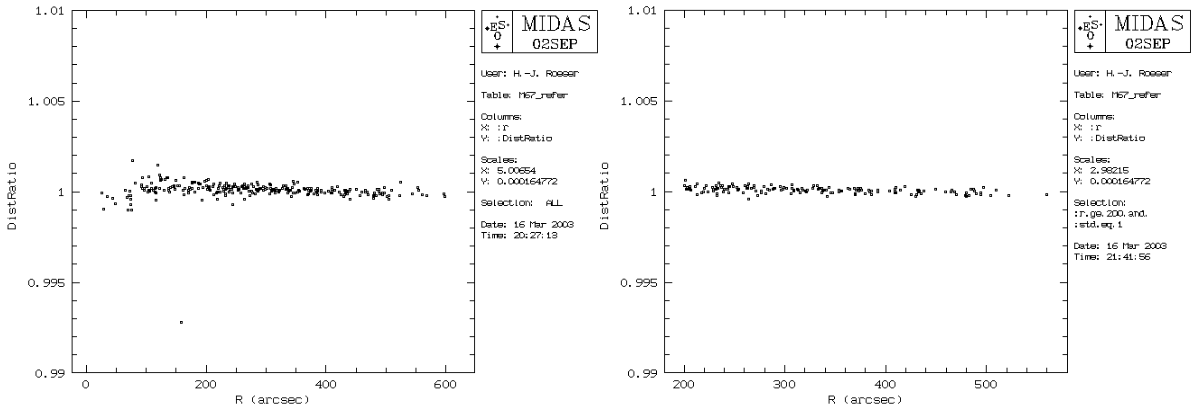
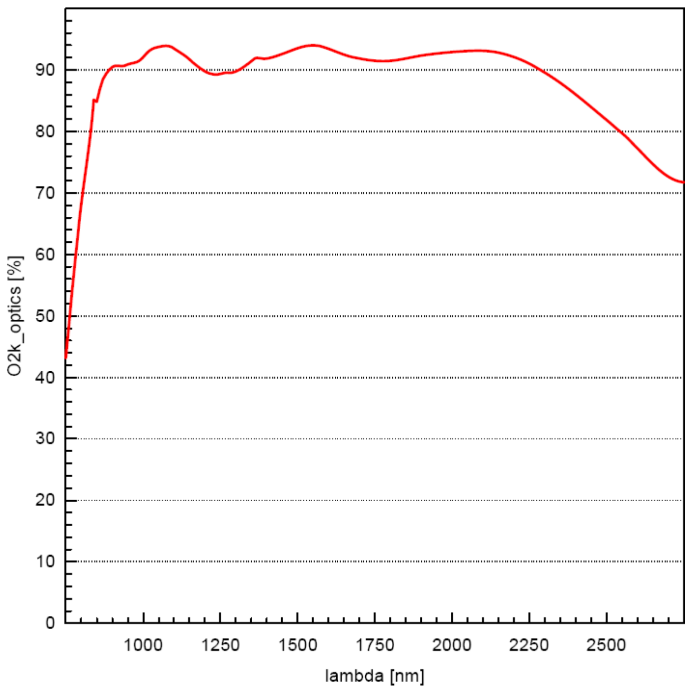


Figure 26: Centre to corner image distortion of the OMEGA2000 optics

The ratio of the distance to a star at the centre for all objects, from the measured position on the detector – using the scale determined from the astrometric solution – to the distance calculated from the RA and DEC positions.

Transmission of the optics was calculated from the transmission curves supplied by the manufacturer for each of the 4 lenses by multiplication.



7.3. *Filters*

For OMEGA2000 a set of 24 different filters is provided (see Appendix 1 for a complete list and filter characteristics). Inside the dewar we have three filter wheels with 7 openings each.

As we need one free opening per wheel and one wheel holds an aluminium blank for dark exposures we can keep 17 filters inside the dewar at one time. Two additional positions are needed for two blocking filters, as the detector is sensitive to beyond 2.6µ, the blocking limit specified for the filters.

Whereas the standard broadband filters *J*, *H*, *K* and *K'* and the most commonly used narrow-band filters like the H_2 2.122µ with the respective continuum filter will always be available, the remaining positions will be equipped with filters requested for the up-coming semester. As we plan to open the dewar at most every half year it is mandatory that you clearly specify your filter needs in the application for observing time. It will not be possible to use special filters on short notice.

7.4. *Baffles*

Due to their sensitivity to the surrounding thermal emission from dome and telescope infrared cameras need an elaborate baffling system. For systems with an intermediate focus, like OMEGA-Cass, a cold Lyot-stop is the most efficient way to block background light. This is, however, not possible in the optical design of OMEGA2000. We thus have to rely on a set of warm and cold baffles, that are meant to reduce the background signal:

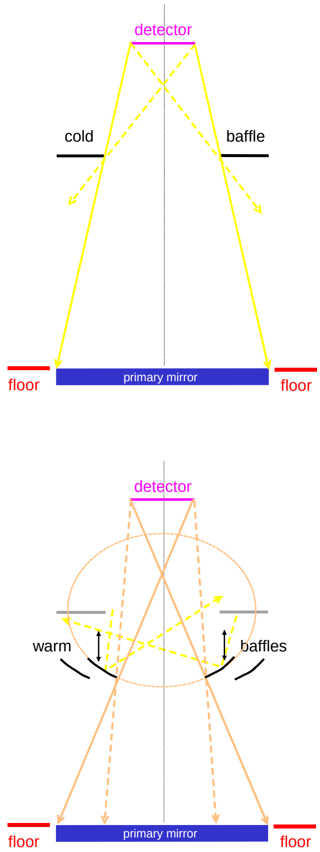


Figure 27: Working principle of the movable warm baffle. With only a cold baffle (top), rays from outside the primary reach the detector. These may be blocked by the movable baffle.

- A cold baffle at the dewar entrance window is placed as far from the detector as feasible to narrow down the solid angle of warm background seen by the detector. In order not to vignette the signal from the sky, this baffle still allows the detector to see parts of the warm dome floor.
- A fixed warm baffle with the shape of an ellipsoid, whose foci are at the rim of the cold baffle, reflects rays from inside the dewar back inside. Rays from the ouside hitting the baffle are not reflected into the dewar. This baffle does not vignette the beam.
- A movable warm baffle of the same principle properties as the fixed warm baffle may be deployed for K-band imaging. It does vignette the beam (constant across the field) but the loss in object signal is more than compensated by the reduction in thermal background: With this baffle deployed no part of the warm dome is seen by the detector. The theory behind this baffle is described in detail by (Bailer-Jones, Bizenberger et al. 2000).

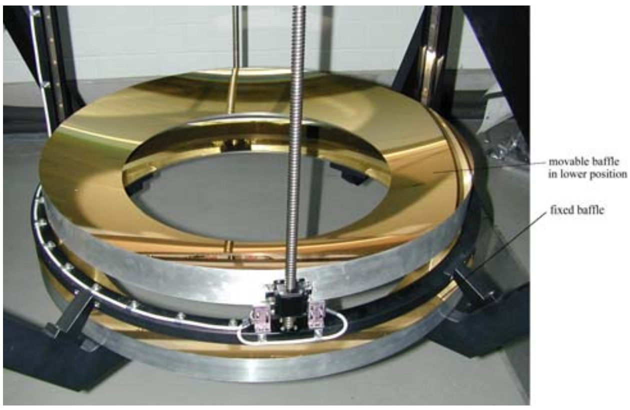


Figure 28: The two warm baffles.

The influence of the movable baffle was tested in a cold winter night. It gave the predicted gain in signal to noise (Faßbender 2003). Tests in a warm summer night remain to be done.

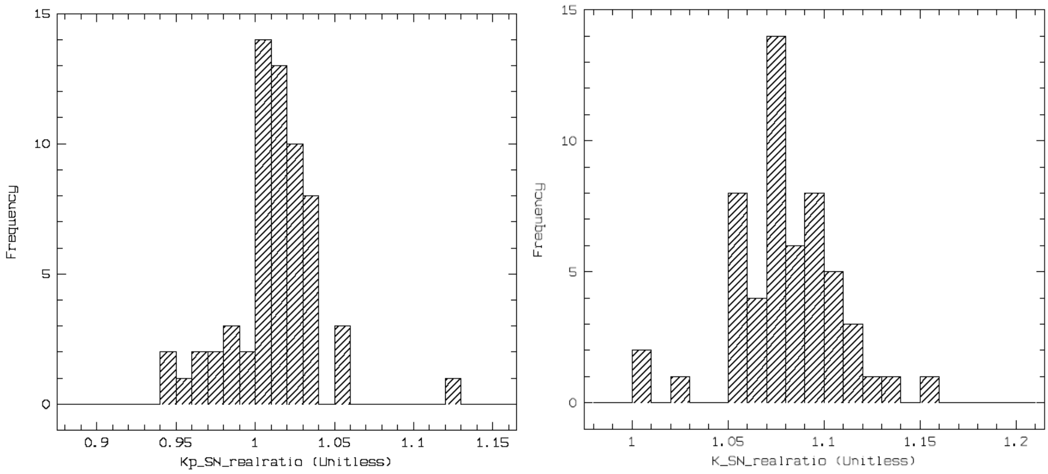


Figure 29: Movable baffle measurement. Histogram of the SNR-ratios with and without the movable baffle. Left panel: K'-filter. Right panel: K-filter.

7.5. *Read-out electronics*

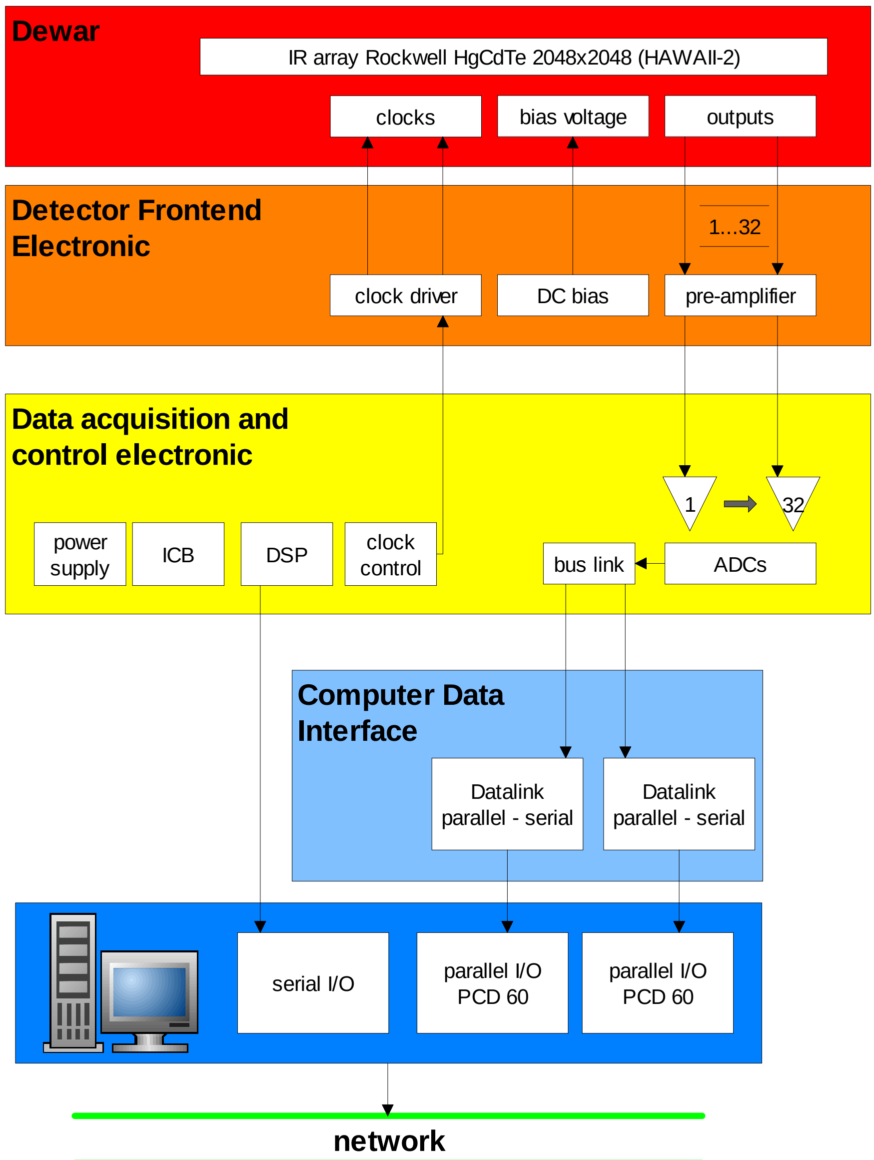


Figure 30: Block diagram of the read-out electronics

7.6. *Control electronics*

As the read-out electronics the control electronics is also mounted in racks on the front ring. Both are sealed in cooling boxes to carry away the heat produced during the observations.

The control electronics is in charge of the following tasks:

- filter wheel movements
- deploying the movable baffle
- monitoring of various temperatures in the instrument and pressure in the dewar

An example of the latter is given below in Figure 31 (see also graph on page 34).

7.7. *Dewar*

The vacuum dewar of the Omega2000 instrument has a cylindrical shape with an outer diameter of 600 mm and a length of 1680 mm. The HAWAII-2 detector and all other inner parts are cooled by liquid nitrogen to a temperature of about 77 K. To reduce the heat load on these components, three radiation shields are nested into each other. The large dewar entrance window is made of fused silica with a diameter of 350 mm and a thickness of 20.7 mm.

The liquid nitrogen is stored in two vessels that can be filled on the telescope through the upper side of the dewar. One of the nitrogen tanks is directly connected to the inner radiation shield and is referred to as the inner vessel in the following. Its capacity is about 47 litres. The outer vessel, with a capacity of about 72 litres, is connected to the second shield. Both nitrogen vessels are only filled half to allow a maximum tilt angle of the telescope of ± 90°, *e.g.* for balancing of the telescope and nitrogen filling in the prime service position (see image on cover). With both vessels filled up to half of their capacity and all cooled parts in thermal equilibrium, the dewar retains a temperature of 77 K for about 34 hours.

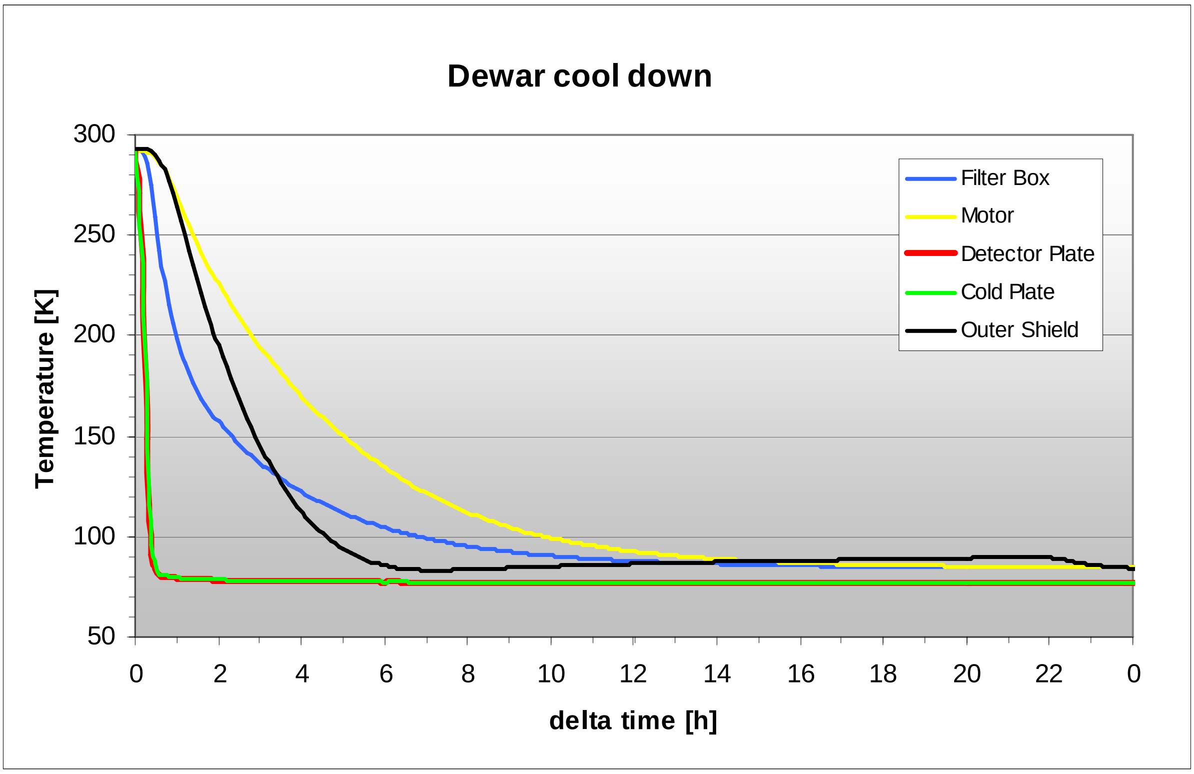


Figure 31: Monitoring the dewar temperatures during cool-down.

8. The 3.5m-telescope

Although the telescope system is pretty much independent from the instrument control, there are some parameters that must be set correctly within the telescope software in order for OMEGA2000 to work properly.

Coordinate system

The 3.5m-telescope knows three different (software) coordinate systems:

- AD is the Right Ascension / Declination. Here an offset in RA specifies the rotation of the hour axis in arcsec.
- XY is the detector system. Offsets in X are the actual movement of the objects on the detector, *i.e.* the cos(δ) is taken into account: $\Delta X = \Delta\alpha * 15 * \cos(\delta)$.

  Please note that you will not come back to the origin if you move the telescope *e.g.* in a rectangle of equal sides due to the field rotation described in Section 5.1. The observing utilities use this coordinate system.
- UV is the rotated detector system. Here any rotation of the mounting flange is also automatically taken into account. This is not relevant for OMEGA2000, which is mounted at a permanently fixed angle of 0° on the front ring.

For the observations you should select the XY system! The MIDAS procedures do this automatically.

Coordinate zero-point

For object acquisition and tracking the telescope software makes use of a pointing model, which takes into account any misalignment of the telescope's axes as well as flexure in the telescope structure. The 0^{th} order parameter of the pointing model is the zero-point offset for both axes of the telescope. This value should be set by Calar Alto staff, who also select the appropriate pointing model. Should the zero-point not be correct, you will not find your objects. Here is the correct value:

```
@KORPAR_T_NULL = -163.3
@KORPAR_D_NULL = 0
```

To check the pointing accuracy, use one of the stars in the astrometric fields provided in Appendix 8. The tables with the positional data from the M2000 and the UCAC2 catalogues are to be found on fire35 in directory /disk-a/o2k/MANUAL.

Focus position

The nominal focus position for OMEGA2000 is 22700 (T = 10°C). The temperature coefficient is –165μ/°C. Make sure the focus automatic, which compensates thermal expansion due to temperature variations as well as flexure, is activated during your observations.

Tip-tilt

The four Serrurier trusses can be set individually to incline the front-ring. For OMEGA2000 all four focus readings have to be identical, *i.e.* no tilt in the fronting. You can check the current position of the four trusses with the command `ReadFocus` in an xterm at the telescope control computer t35.

Note: OMEGA2000 has no auto-guider and totally relies on telescope tracking. Thus one should not run excessively long dither sequences. It is recommended to re-align the telescope after at least one hour of observing or use the auto-guide feature in the observing macro.

9. The graphical user interface (GUI)

The software handles all infrared cameras at Calar Alto. Therefore the observer, once having used one system, will easily feel at home with the other cameras. Slight changes are introduced only due to different hardware, *e.g.* the number of filter wheels in the dewar.

9.1. *Login to the system*

At any one of the dual monitor X-terminals you can log into the `fire35`. Please choose the CDE desktop at login:

`User: o2k`
`Password:` *ask Calar Alto staff !*

The following panels will appear upon login on the otherwise empty screens:

Left monitor

Right monitor

Figure 32: Control panels on the display after login as user *o2k*.

The central rectangular blue buttons labelled “OMEGA2k” and “Pipeline” on the left and “General” *etc*. on the right hand screen are meant to select the appropriate desktop for the tasks indicated. Once the desktop is activated the corresponding tasks are started by clicking on the panel to the right with the OMEGA symbol or the MPIA logo, respectively. These buttons, as do all the others, hide pop-up menus which can be opened by clicking on the small triangle above the symbol to show the following OMEGA-specific tasks:

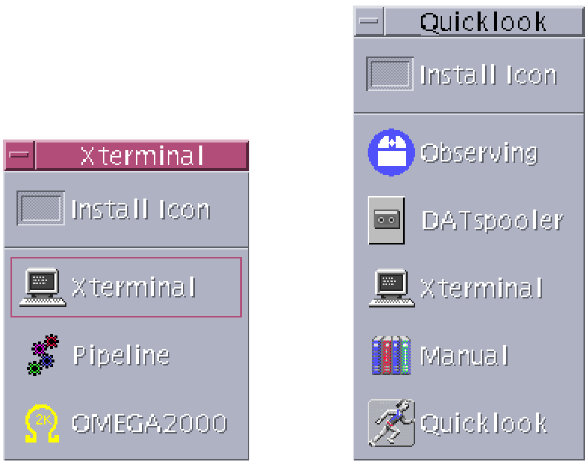


Figure 33: The available screens to operate OMEGA2000

Clicking on a task opens an X-terminal and starts the specific task, e.g. the MIDAS session for the pipeline. If you click onto the OMEGA2000 or the MPIA symbol without opening the pop-up menu you directly start the OMEGA2000 GUI and the observing window, respectively. Please note that in case of MIDAS sessions the X-terminal will automatically be closed if you terminate the session.

The following setup proved to be useful:

Left hand screen: GEIRS GUI and MIDAS session for pipeline reduction

Right hand screen: General (DATspooler), MIDAS sessions for Quicklook and Observing

The MIDAS-sessions start automatically after pressing the pull-up buttons. You have, however, to set the path in each session (`ch/dir` ...) to where the data are (save-path set in GUI).

Currently it is best to start the desktops in the following sequence in order to not loose colours in those windows where they are desperately needed:

1. GEIRS GUI
2. DAT spooler
3. MIDAS session for quicklook
4. pipeline
5. observing

We hope to solve the colour problem in the near future with the LINUX-PC to be used as an X-terminal with the dual screen.

9.2. *Start-up*

Starting the GUI by pressing the OMEGA2000 button will show the start-up screen

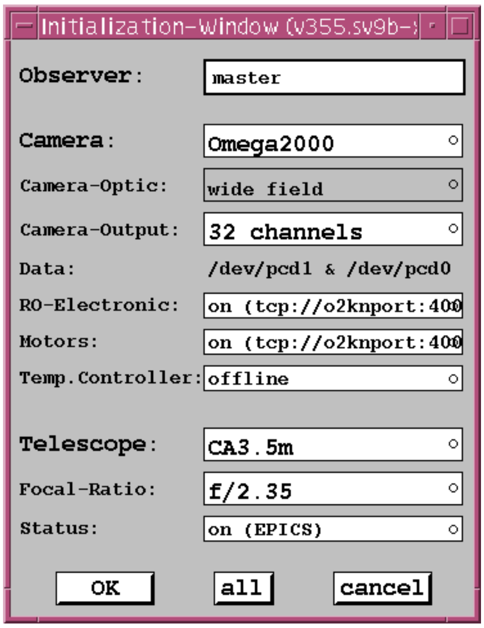


Figure 34: Welcome screen of GEIRS to start the instrument.

Please enter your name as observer, the rest should be set as in the figure. After you give OKAY, the GEIRS windows (GEIRS = Generic InfraRed Software) appear and the desktop shown in Figure 35 will appear (please note that in this example the telescope had been switched to OFFLINE. Therefore the telescope GUI is not shown!).

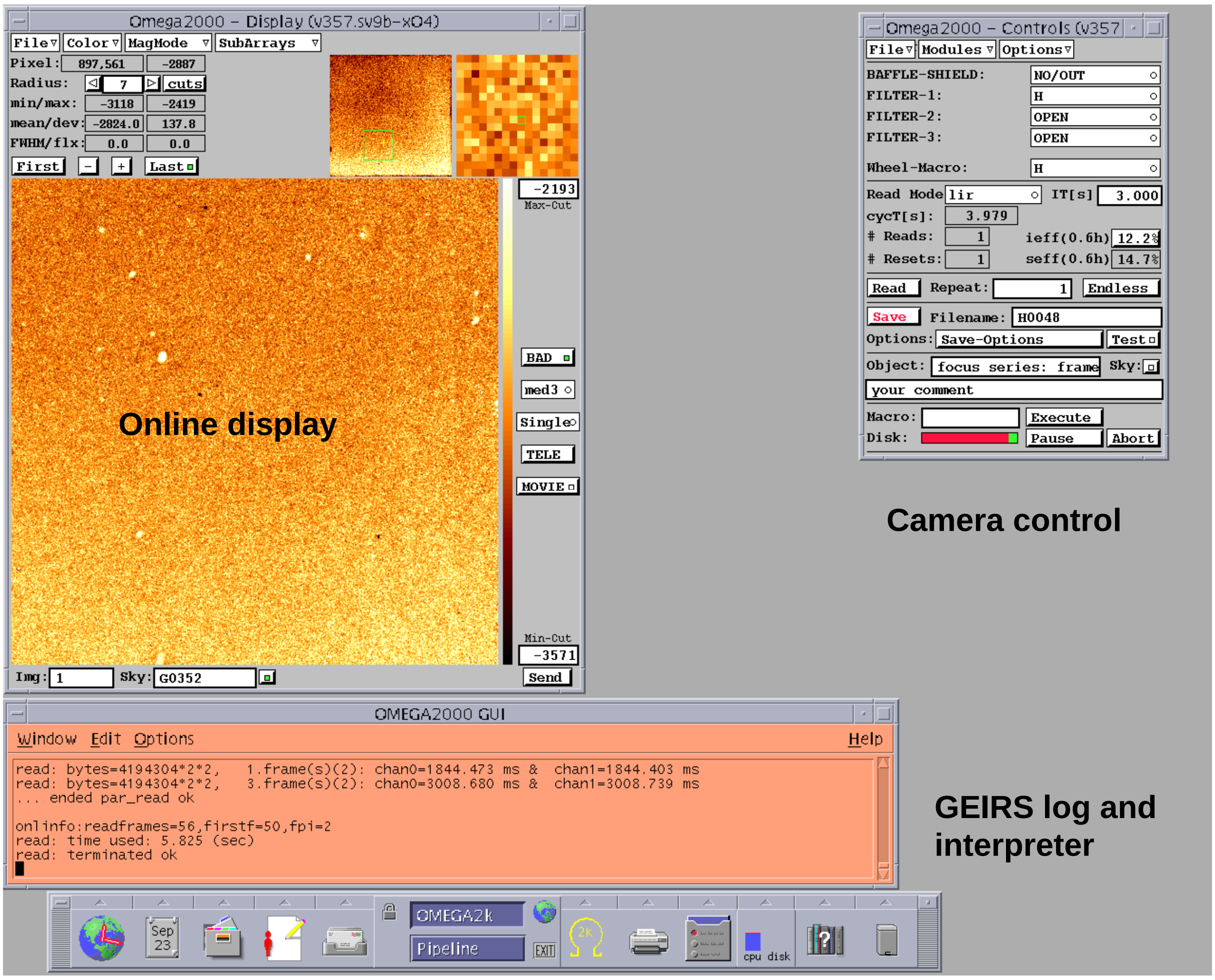


Figure 35: Desktop to operate OMEGA2000 with the camera control, the online display and the log window.

9.3. *The GUI's windows*

9.3.1. Camera control window

This is your interface to the OMEGA2000 camera. Fields are changed by clicking into them. However, editing in the fields is not possible. You always have to type your text anew.

In the top row three pull-down menus provide further options:

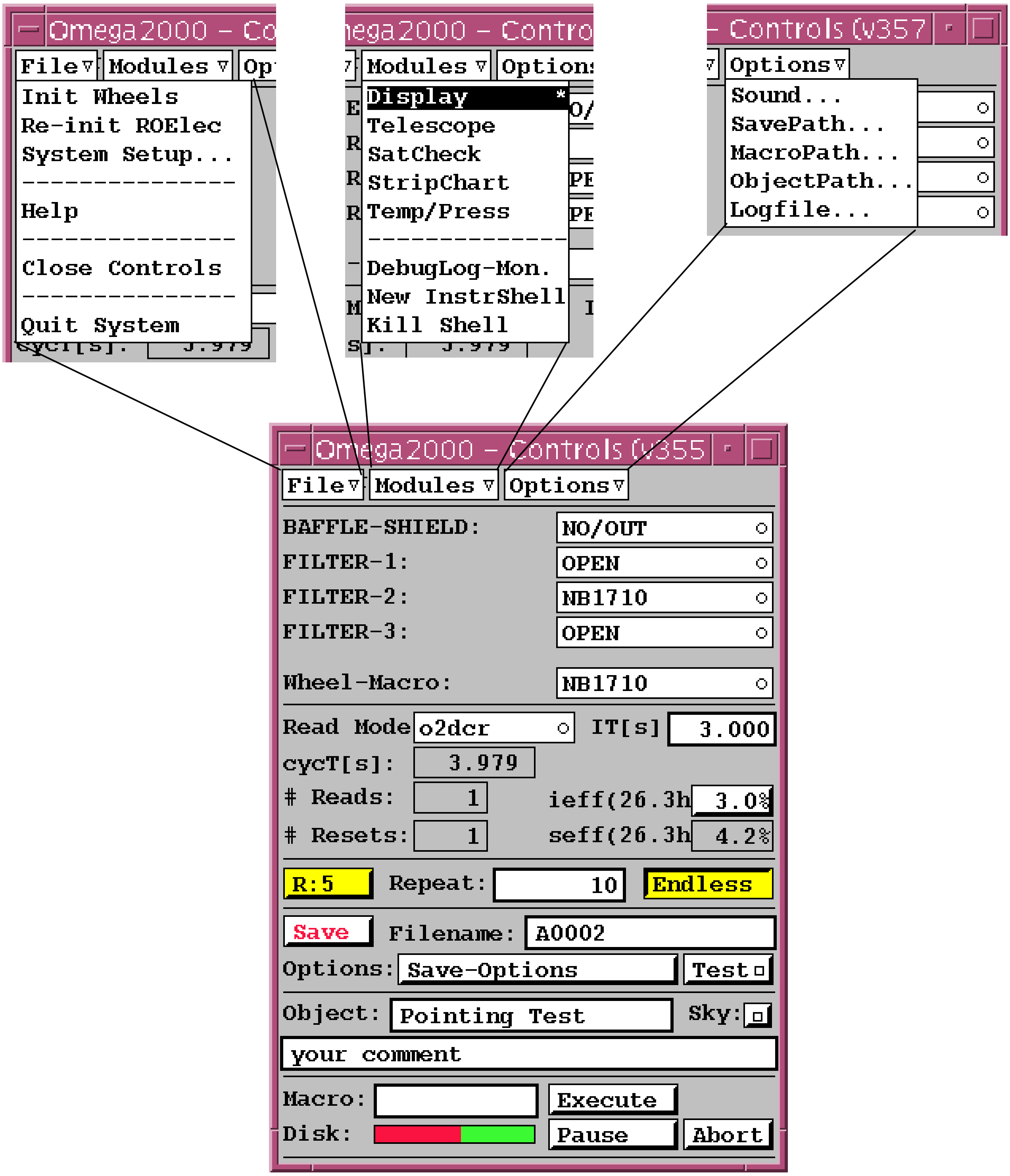


Figure 36: The camera control window with its drop-down menus.

The drop-down menus provide the following options:

File Menu

- **Init wheels** sends all of the filter wheels back to their zero positions.
- **Re-init ROE** resets the read-out electronics
- **System setup** will bring up the initialization window.
- **Help**
- **Close controls**
- **Quit system** will quit the GUI.

Modules Menu

The modules menu starts the different modules, each of which has its own description section.

- **Display** - should start automatically.
- **Telescope** Telescope control - should start automatically.
- **Satcheck** Turns on audible saturation warning.
- **Stripchart** Keeps a visual record of the past several images.
- **Temp/Pressure** Displays a graph with the pressure and various temperatures inside the dewar.

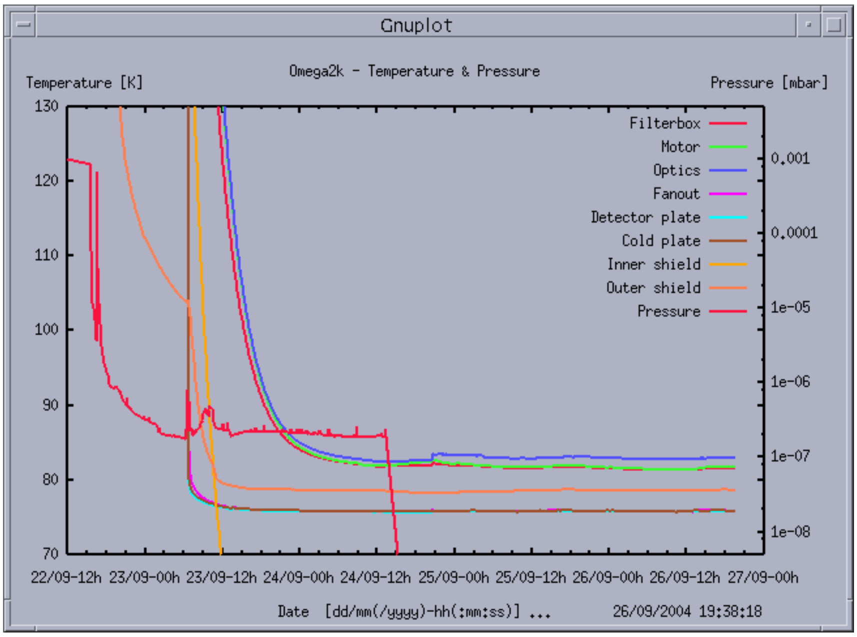


Figure 37: Monitoring temperatures and pressure of the dewar.

Options Menu

- **Sound** calls up a sound menu, where a specific sound file can be associated with a variety of different functions (such as telescope moves, completion of a read ...).
- **Savepath, Macropath, and Objectpath** tell the GUI where to save data and where to look for macro and object files.
- **Logfile** specifies where the log file is kept. Note that the logfile path needs to be re-entered each time the GUI is restarted and the other path parameters should be checked!

Below the drop-down menus various fields display the status of the camera and allow the setup to be changed:

Baffle-shield

To suppress background radiation at long wavelengths, the baffle may be put into the deployed position (see Section 7.4)

Filter wheels

While the control panel allows for addressing each wheel separately, all requests for filters should be made from the wheel-macro panel, where all standard observing configurations are available. The individual filter wheels should say moving as the wheels are being repositioned, then display the actual position (filter name, open, or blank) when set.

Read setup

Mode The different read modes available are described in detail in Section 3.2. For standard broad band observing this should normally be left at double correlated read (called o2dcr or rrr).

IT(s) is the integration time in seconds. Note that the minimum exposure time with Omega2000 is 0.8 seconds except for mode *lir*, where it is 1.6sec! Keep this in mind when doing broad band observations under high background conditions or when observing bright objects – the array can easily saturate during these 0.8 seconds of "dead time" while the array is resetting.

cycT[s] is the total time for one read cycle in seconds.

 # Read / # Resets is the number of reads and resets executed in the current read cycle.

ieff(elapse time) gives the observing efficiency as the ratio of integration time to elapse time.

seff(elapse time) gives the system efficiency as the ratio of time for read-out to elapse time.

Repeat is the number of images *N* with the specified exposure time *T* which will be taken each time a read is executed (read-cycle). The total exposure time will then be *N* x *T* seconds. The maximum number of images depends on the setup of the computer memory. It is currently 23 images. The current sequence number of the **reads** is displayed to the left (READ button, see below). **Endless** may be pressed to start an endless loop of reads. The images are read out with the current integration time and dumped to the display, but are not saved. This is useful for positioning the telescope before *e.g.* starting a macro.

Read The read button executes a read using the current exposure time and number of repeats. On completion of a read, the images are not saved unless autosave is selected under the save option.

Save The save button saves the most recent image(s) obtained using the currently defined save options.

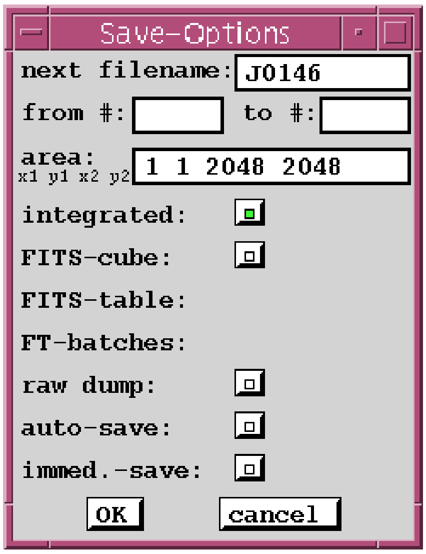


Figure 38: Save options window

Filename The name of the next file to be saved by pressing the SAVE button at the beginning of this line or by issuing a save-command from a script. One can either specify a name or a root. In the latter case the filename is the root plus a four digit integer, which will be automatically increment by one each time a save is executed. By specifying the root, the system looks for the highest free filename. If a filename ends with a number this number will be increased.

Save-Options Calls up a save configuration panel which defines the default way in which to save images. The main choices are whether to save individual exposures as separate disk files, or to integrate them (sum) and save only a single disk file. Note that the save options are overridden by any options specified in observing macros. For example "save -f 2 -i" in a macro will integrate from image 2 to the end of the series, and save only a single file, even if the save options specify saving images separately. Turning on auto-save will execute a save after every read, without clicking on the save button.

Test gives “`test`” as a root name for the next image, which will not be saved to tape. After the test exposure the previous file / root name is restored.

Object is the object name which is written into the fits header under the keyword "OBJECT" for the current image. It will be updated automatically if object selection is done through object files (recommended), or can be changed by hand.

Sky Clicking on the sky button writes a sky flag into the fits header, but otherwise has no effect.

Comment to be included in the FITS-header.

Macro Here, you specify a macro to be read into the macro buffer. The filename, without the .mac extension, is all that is necessary (all macros must have the .mac extension). The macro file must be in the MACROS directory specified under the macro path in the options menu (see above). Please refer to Section 10 on page 45 for the macro syntax and commands.

Execute, Pause, and Abort control the execution of observing macros, reads and running MIDAS-prgs. Note, that if a pause or abort is issued, the macro will continue executing until the current command is completed! Check in the command window to be sure that the pause is in effect. Clicking on continue will continue executing the macro after the pause. This is useful when changing the dome slit segments. In the case of a MIDAS-prg running, the abort will take effect only after the next major loop, *e.g.* the next focus setting in a focus test or the next dither position in case of an observing sequence.

Disk The green portion of the bar indicates the fraction of the selected disk which is still available. If you are taking lots of data, keep an eye on this. The GUI also issues an audible warning when the disk is getting close to full (assuming you have not turned off the sounds!).

9.3.2. Real-time Display

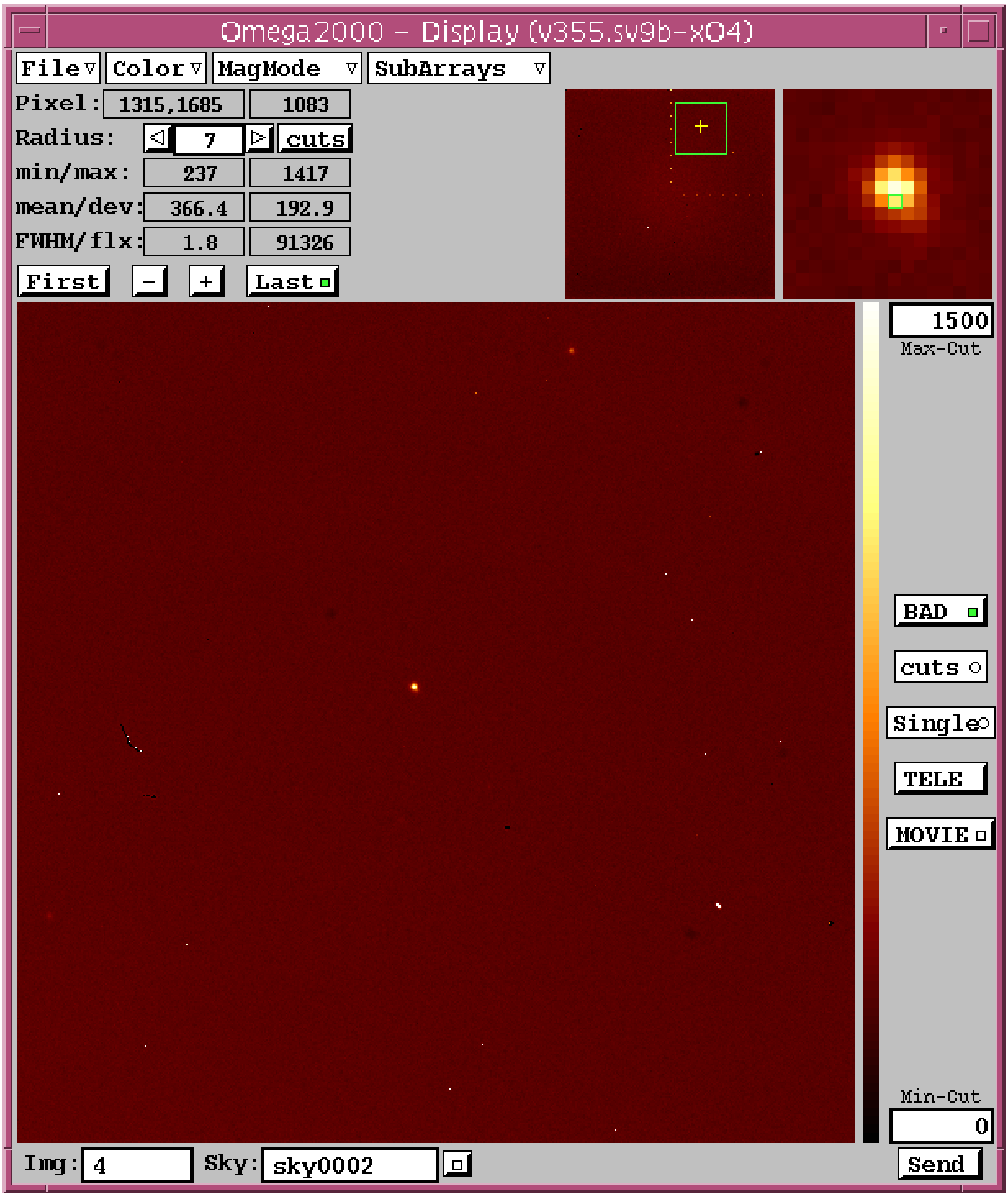


Figure 39: Real time display

The display tool shows one frame of the current set of data. Some on-line data processing techniques are available. These techniques affect only the displayed data, only the raw data is saved to disk. In addition there are various helpful options to move the telescope to certain positions.

File Menu selects the basic display size:

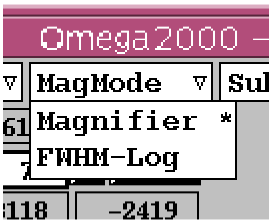
- **256** changes display window to 256 screen pixels square. The full Omega2000 image is displayed, binned 8x8. Note that in general you will not see your objects in highly binned mode as they most often will happen to fall between the displayed pixels!

- **512** changes display window to 512 screen pixels square.
- **1024** changes display window to 1024 screen pixels square.
- **2048** changes display window to 2048 screen pixels square. The display will not fit onto your monitor screen in this case!
- **Slave** Opens a second display window at a size of 1024x1024 pixel on a second screen.
- **Quit** Quits the display module. It can be restarted by selecting "display" under the module menu of the camera control window.

Color Menu selects the colour look-up table for displaying images.

- **gray** is a black-and-white colour look-up table.
- **temp** is the standard "temperature" colour table.
- **bb** is the standard blackbody colour table.

MagMode Menu switches between the zoom window and a measurement of the image seeing.



- **Magnifier** Zoom window, this is the default mode.
- **FWHM-log** Measures the FWHM of the indicated object each time a new image is displayed, and plots a running history of the values. This is useful for rough focusing. Note that to get reasonably accurate measurements of the FWHM, the aperture of the box used (set with radius, see below) must be large enough to include a couple of rows of sky pixels around the object you are measuring!

Pixel When the cursor is in the image display window, the pixel position and counts in that pixel are displayed here.

Radius Sets the radius of the small cursor box in the image display. See the above note on FWHM-log about measuring the seeing.

min/max Show the minimum and maximum values of the pixels within the cursor box.

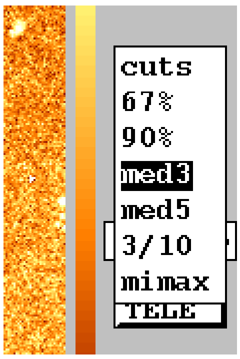
mean/dev Shows the mean and standard deviation of the pixels within the cursor box.

FWHM/flx Shows the FWHM and total flux (in counts) of an object selected with the cursor box.

First - + Last Controls the display of a series of images. Unless you need to review a set of images to determine, for example, whether the seeing was good enough to bother saving the data, just leave this on last.

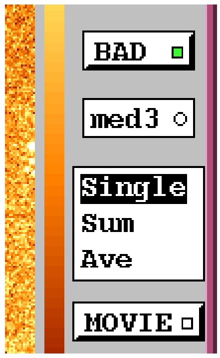
BAD Toggles between displaying the bad pixels (in red) or not. Note that the bad pixels are ignored when determining display cuts only if the bad pixels are turned on. The bad-pixel mask is stored in path ??

Cuts Display stretch control. This button brings up a menu with various options for determining the minimum and maximum display levels. The options include:



- **Cuts** Allows you to enter your own minimum and maximum display levels in the "Min-Cut" and "Max-Cut" windows.
- **67%** Sets the display range to cover 67 % of the full dynamic range of the data.
- **90%** Sets the display range to cover 90 % of the full dynamic range of the data.

- **med3** Sets the display from (mean - 3sigma) to (mean + 3sigma).
- **med5** Sets the display from (mean - 5sigma) to (mean + 5sigma).
- **3/10** Sets the display from (mean - 3sigma) to (mean + 10sigma).
- **minmax** Sets the display range to cover the full dynamic range of the data.



Min-Cut & Max-Cut These windows show the current minimum and maximum levels used for the display. They will automatically update each time a new image is displayed except if using the "Cuts" op tion.

Single/Sum/Ave Single will display each individual read as it comes off the camera. Sum will display the sum of all images taken in the current series. Average displays the average of all images taken in the current series.

Tele Provides for offsetting the telescope directly from the image display, which is useful for centring standard stars or science objects. Click on the "tele" button to get a green circle. Place this circle on some object on the display and click there?? Calculating centroid??. Move the cross which appears to where you want this object to be moved.

Movie Plays a movie of the series of exposures currently in memory.

Image shows which image in a series of repeated exposures that is currently being displayed.

Sky The "sky" button (small square) tells the computer to subtract a sky frame from the images before displaying, and is on when the square appears green. The file used for the sky frame is specified by name in the window to the left of the button. This sky-subtraction also effects the pixel values displayed in the upper part of the window. Be aware of this when checking count levels / saturation of a displayed image!

Send Send the current image to the data base of the strip chart.

9.3.3. Telescope control window

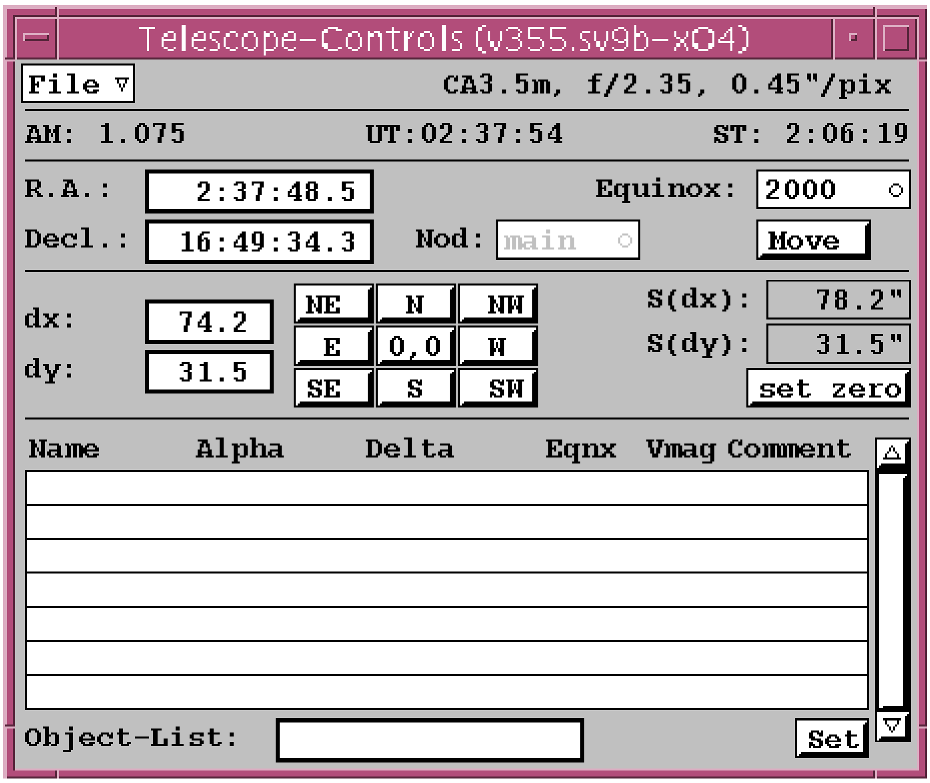


Figure 40: Telescope control window

Basic control of the telescope, such as moving to an absolute position or offsetting from the current position, is done on the telescope control panel. The basic information from the telescope, such as airmass, UT, and current telescope position is also displayed here. This GUI panel should start automatically when the GUI is first initialized. If not, you can call it up from the camera control window in the menu *Modules*.

File Menu:

- *SAO map*: Calls up a separate GUI panel which shows the area of sky where the telescope is pointing, including nearby SAO stars. This panel is described in more detail below.
- *Airmass*: Graphical display of the current airmass and plot of the airmass history for the currently set object.
- *Quit*: Quits the telescope control panel, but not the GUI. This module can be restarted from the modules menu on the camera control panel.

Moving to an absolute position An absolute position can be entered directly in the RA and Dec windows. After setting the equinox, the position can be sent to the telescope by clicking on the move button. Note that the telescope does not actually move - only the coordinates are sent! To move the telescope, you must press the "go" button on the old telescope controls. The RA and Dec windows also display the current telescope position after each offset.

Relative offsets Offsets in arcseconds can be supplied in the dx and dy windows. Clicking on one of the directional buttons in the compass panel will then offset the telescope by the requested amount. The "set zero" button zeroes the cumulative offsets (S(dx) and S(dy)), and the "0,0" button in the centre of the compass returns the telescope to this defined zero position.

Object Files An object file can be given in the Object-List window (the .obj extension is not necessary). Objects can be selected with a single click, and set with the set button. Setting an object sends the object's coordinates to the RA and Dec windows. These can then be sent to the telescope computer by clicking on move as described above. A useful feature is that when an object is set, the airmass panel will display the object's current airmass in graphical form, though there is no obligation to actually move to the object. See also Section 9.7 on page 44 for a description of the format of such an object catalogue.

9.3.4. SAO Map Window

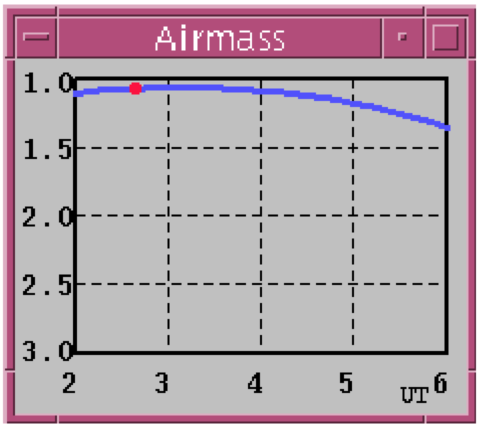
The SAO map shows an area of sky centred on where the telescope is pointing. The display includes all of the SAO stars in the vicinity, colour-coded as to spectral type (Blue=O,B, Green=A,F, Yellow=G, Red=K,M, Black=unclassified), where the size of the dot indicates relative brightness. The dashed red square shows the size of the camera field of view. A scale bar in the upper left corner of the image gives a scale reference. Zooming the display in or out is done with the ***two arrow buttons*** in the upper right corner of the window.

Stars can be selected by clicking on the image, with additional information (SAO number, spectral type, and visual magnitude) appearing at the bottom of the window. The coordinates can be sent to the telescope computer with the ***Move*** button.

A log of all previous exposures is kept, displayed as green squares on the SAO map. This feature is useful for following the progress of observing macros. ***Clear Frames*** will clear the display of the old frames, though future frames will continue to be displayed.

The SAOmap can be turned off by reselecting the "SAO map" option in the file menu of the telescope control panel. Using the "quit" option in the xwindows menu will also kill the telescope control panel!

9.3.5. Air Mass Window

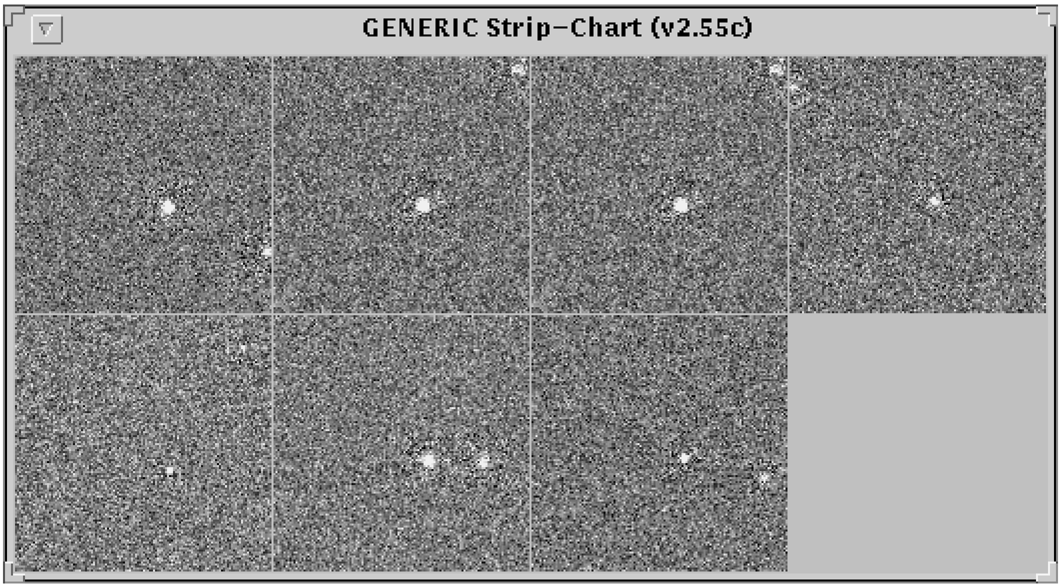


The airmass window graphically displays the airmass of the currently selected object (red dot), as well as a tracing of the airmass over several hours of time (blue line). The number of hours depends of the width of the window. This feature is particularly useful when used in conjunction with object files. Objects selected and set from an object file will show their current airmass in the airmass window. The airmass plot will automatically reset to the current telescope position whenever the GUI queries the telescope computer for the current position (for example, when a read command is finished).

The airmass window can be turned off by reselecting the "Airmass" option in the file menu of the telescope control panel. Using the "quit" option in the xwindows menu will also kill the telescope control panel!

9.3.6. Strip Chart Window

The strip chart is a data base for images taken with the GUI. The images are always displayed in a 128 x 128 pixel format. To add an image to the strip chart you have to press the button *send* in the display window. The number of displayed images depends of the size of the window. If you increase the size of the window, more images are displayed.



9.4. *The MIDAS sessions*

Figure 33 shows the desktops foreseen for the operation of OMEGA2000. Three of the screens are for MIDAS sessions. Their purpose is described in the following sections. During launch of each of these you will be queried for the current data directory. The MIDAS sessions need to be run in the path where the data are. Should you change this path later, please then use the `change/dir` *path* MIDAS-command to set the path for the MIDAS session. Do not use the UNIX command `$cd` *path*. This will not work. However, `$pwd` shows the current MIDAS path[4].

9.4.1. Quicklook

The green X-terminal is the only session which is launched with a graphic and a display screen. So this is the one to be used for any interactive work. On the other hand it should not be blocked by launching a long observing session from here. The following utilities need this window:

- focus test (Section 13.1, page 50)
- offsetting the telescope to pixel accuracy (Section 13.8, page 72)
- seeing measurement (Section 13.7, page 72)

This is MIDAS session #31.

9.4.2. Observing

The white X-terminal is ment to host observing commands that take a long time to execute, *e.g.* the ok2/dither (Section 13.6.1, page 63). This way one can take a closer look at previous images or results from the pipieline in the quick-look terminal.

This is MIDAS session #32.

9.4.3. Pipeline

The yellow X-terminal is reserved for executing the online data reduction with the OMEGA2k pipeline (Section 14, page 76).

This is MIDAS session #33.

As observing commands may require the availability of the display etc. it is essential to use the appropriate MIDAS sessions. For some more critical commands we check in which window the command is launched and abort if this is not the appropriate one.

Any further MIDAS sessions (launched with `inmidas -p #ii`, where ii is the session number) must not use the session numbers 31 to 33.

A few basic MIDAS operations *e.g.* to display an image are given in Appendix 12.

[4] In general, all UNIX commands can be issued from within MIDAS, if they are preceeded by $-sign.

9.5. *Taking data*

The windows introduced thus far are the environment in which one takes data manually (including the use of GEIRS macros, see Section 10). This is useful for tests or special calibrations. For taking standard calibrations (darks, flats), focus the telescope and dither science frames it is strongly recommended to go to the MIDAS environment and use the procedures described in Section 12.

9.5.1. Setting up the camera for an exposure

Before you start, make sure you have selected the proper paths for your data etc., see Figure 36 at upper right. You should also set the root name of the files to be stored on disk, which is also done in the camera control window.

The instrument is completely setup in the camera control window. Here you select the filter, the read-out mode and the exposure times, to name the most important. You should use the filter macro to select your filter. This is faster than turning the wheels individually. Furthermore, the macro automatically inserts also a blocking filter, if necessary.

9.5.2. Taking exposures

An exposure is taken by pressing the READ button (below centre in the camera control window). Although this exposes the image, it is only read into the memory of the instrument computer. There you can use it to take a look at it on the real-time display, measure background level, seeing etc. there. If you decide to keep the image, you also have to decide on the mode on how to save the data (*e.g.* as a FITS cube, individual images, stacked images) by opening the SAVE-OPTIONS window with a click of the right mouse button onto the save-options button. Once set you save the data by pressing the SAVE button. Due to the double buffering, an image may be saved while the next one is already been taken.

9.5.3. Image inspection with the real-time display

The features of the real-time display are described in detail in Section 9.3.2. Please note that you do not manipulate the raw data on disk with these operations.

9.6. *Saving data*

The data are stored on one of the disks of the instrument computer under the path you have specified under SavePath in the Options Menu of the camera control window. You are advised to create a path with your name under `/disk-X/o2k/DATA/`*`your_name`*, where `X` is b, c or d for the data disks. Other locations must only be used after permission by observatory staff. The files are stored as FITS files and are not write protected (!).

It is strongly recommended to start the DAT-Spooler right at the beginning of the run. It automatically copies a file to tape immediately after it is written to disk (see Appendix 4 on page 95). This way you need not worry about your data being safe. The DAT drive is a DDS4 so you can only use the DDS4-tapes. A tape holds roughly 1200 images, depending of course on your save mode. Make sure you bring enough tapes with you!

If you prefer, you are always free to prepare your copies with tar. This is not recommended, however, as tar is rather unsafe, as it copies everything as one single file. Also later access to a single file is much more complicated than with FITS tapes, where images are stored as individual files.

As long as the DAT-Spooler is not able to write to two DAT drives at the same time we recommend to make a security copy of your data with Calar Alto's `fitscopyx` utility.

Your intermediate results, e.g. from the pipeline can either be copied to tape with the DATspooler (see *Using the spooler from an xterm* on page 95 for instructions on how to manually copy files) or you may transfer them to `o2klinux` and burn it on a DVD or CDROM there.

9.7. *Object catalogues*

You can create your own object list in the following format:

```
Object name | Alpha | Delta | Equinox | pm.A | pm.D | mag | Comment
```

Example:

```
HD 225023| 0:00:11.8| 35:32:14.0|1950|0.0000|-0.004|6.96|J=7.97
G158-27| 0:04:12.0|-7:47:54.0|1950|-0.056|-1.85|7.43|J=9.31
HD 1160| 0:13:23.1| 3:58:24.0|1950|0.006|-0.013|7.04|J=7.06
HD 3029| 0:31:02.3| 20:09:30.0|1950|-0.0001|0.011|7.09|J=7.25
Gl 105.5| 2:38:07.6| 0:58:57.0|1950|*|*|*|*
HD 18881| 3:00:20.5| 38:12:53.0|1950|0.0001|-0.030|7.14|J=7.12
```

Note: The line | character is used as a separator between fields.
If you don't want to put in numbers in some fields, you still have to use a * character as a place holder.

Important

- If you have negative declination less than one degree then you must place the negative sign before the minutes *e.g.* `0:-13:45.6`
- The required fields are: Name, Alpha, Delta, Equinox
- The optional fields are: pm.A, pm.D, mag, Comment
- pm.A and pm.D are in units of arcsec/century.
- All object list files must have the extension: *.obj

Some useful catalogues (focus fields etc.) are found under /disk-a/o2k/OBJECT_CATs. The current catalogues are

- focus_fields
- astro_fields
- faintstd
- arnica

Please note:

For the time being the equinox in the catalogue and the one set in the telescope GUI have to be the same. Otherwise the telescope will not position properly!

10. Macros

You can prepare macro files in advance to carry out specific, normally reoccurring, tasks. Please note that the macro utility is sequentially oriented. *I.e.* you have to specify a macro command for every action you normally would take at the camera GUI. It does not provide conditional and loop capabilities. However, every macro command may be issued with the prefix `cmd_o2000` from a shell, *e.g.* a MIDAS procedure (the utilities presented in Section 12 make heavy use of this feature).

The following example shows a simple macro that moves a star to five positions on the detector, starts a read at each and saves the data.

Example:

```
read            ;start the 1st read
sync            ;wait until all previous commands are finished
tele rel 25 25  ;move the telescope
save -i -f 2    ;save the data as integrated, starting from the second frame
sync tele       ;wait until only telescope move is finished, save will con-
                tinue
read            ;start the 2nd read
sync            ;wait until all previous commands are finished
tele rel -50 0
save -i -f 2
sync tele
read
sync
tele rel 0 -50
save -i -f 2
sync tele
read
sync
tele rel 50 0
save -i -f 2
sync tele
read
sync
tele rel -25
25
save -i -f 2
sync tele
```

All macro files must have the extension ".mac" and are started from the camera control window (lower part, see Figure 36).

Macro Commands

In a complete list of macro commands is given. These commands and syntax can be used in macros or typed directly into the command window. *Use with caution* – some commands are better left out of macros! For example, **quit** will exit a macro at the point it occurs, no further instructions in the macro will be executed. Also, if **interactive** is on, and **ls**, **dir**, or **history** are used in a macro, the macro could stop executing and wait for a carriage return.

Double buffering

It takes a considerable amount of time to transfer the data from the camera and save it to the hard-drive on the workstation. To reclaim some of this otherwise lost time, Omega-prime has been configured with two image buffers. Thus, a new image can be read out while the previous image is being saved. To implement this feature, the macros should be written as in the example above, with a sync tele after the telescope offset and save commands. The GUI will then only wait until the telescope move is completed before starting the next read (the save command may still be in progress). When observing in the K band, the increase in efficiency of observing (the fraction of time spent actually integrating on source) is significant. With 3 second integrations, 11 repeats, and saving images 2 through 11 as an integrated image, efficiency jumps from 33% to 40%.

Using macro commands in a shell script (or MIDAS prg)

All of the above macro commands can be used in shell scripts by preceding them with the string `cmd_o2000.`

Example for the use of macro commands a MIDAS procedure:

```
set/format I1 F6.1
! set image parameters
$cmd_o2000 crep {crep}
$cmd_o2000 itime {itime}
$cmd_o2000 sync

$cmd_o2000 filter {P4}
$cmd_o2000 sync
```

11. Trouble-shooting

From time to time it can happen that a process hangs. Mostly you can simply kill the hanging process. Some commands are prepared for this:

- *kill read* terminates a read command
- *kill telescope* terminates any command to the telescope
- *kill wheel* terminates any command for the filter wheels

Type these commands in the interpreter window where you have started the GUI.
If you have any trouble with one of the instruments please report to Peter Bizenberger. We will create a list of problems (and if possible with solutions) to help future observers avoiding the same trouble.

Problem:
You can't start the GUI
Solution:
Type *cleanup* before you start the GUI. This program deletes all remaining software parts from a previous session.

Problem:
Data is useless (counts between 0 and 65000, randomly distributed) and the *Abort* button does not work.
Solution:
The fibers are connected wrong.

Problem:
Anything seems to work well but there are no stars.
Solution:
1. Check the last button in the display window.

Problem:
Message 'can't allocate info page' and you can't start the GUI
Solution:
There is still a shared memory socket existing. Delete in the *tmp* directory the *shmsocket*.

12. Observing strategies

12.1. *Minimizing overhead*

There are several sources for overhead during OMEGA2000 observations which critically determine the observing efficiency:

- Telescope movement
- Detector read-out

Telescope movements are especially important if extended objects are to be observed. Here the overhead is determined mainly by the frequency with which sky fields are observed and how distant these are from the target. In the case of sparse fields the dithering with short integration times and/or low number of co-adds also results in appreciable overhead.

The detector read-out is currently limited to `lir` (line-interlaced mode) in 32-channel mode. For the time being also `idle break` should not be used as it results in images which are not properly flatfieldable. The current default is thus `idle wait`. In this situation the overhead can become substantial and it is thus mandatory to optimize the settings of integration times and number of co-adds. In general one should aim at low integration times and large number of co-adds. This minimizes the overhead due to the `idle wait` setting. Integration times have, however, a lower bound as the images should be limited by background and not by detector read noise.

Example: If one takes images with 100sec integration time (*e.g.* for narrow band imaging) the following overhead (without telescope movements) have to be expected:

co-add = 1: elapse time is more than 200 sec (due to idle wait, dummy read and actual integration), *i.e.* the efficiency is <50%.

co-add = 5: elapse time is somewhat larger than 600 sec, so now the efficiency is ~80%.

A practical example, which includes also the telescope movements, is a typical observing sequence for the HIROCS survey, where we use command `o2k/dither` with 25 dither positions. The individual exposure time is 3sec, 20 of which are added up in memory (`ncoadd=20`). A complete sequence gives thus 1500 seconds of integration and it takes 38 minutes to complete. Thus the efficiency is 66%.

13. Observing utilities

General Remarks

The utilities described in this chapter are meant to increase the efficiency in the use of telescope time. OMEGA2000 has the same functionality in terms of user interface and macros as the other IR cameras on Calar Alto. Thus users may use their own observing macros.

All functions described in this chapter are MIDAS procedures and have to be called from an active MIDAS session. The context `omega2k.ctx` has to be set for the definition of the utility short-cut commands *`o2k/command`*. All routines use the environment variable `O2K_UTIL` which points to the directory `o2k_utilities`. All paths are defined relative from this top level directory.

All routines can be paused during the data acquisition process by pushing the PAUSE-button in the instrument GUI. The data acquisition is continued by pushing the CONTINUE-button.

All routines can be aborted during the data acquisition process be pushing the ABORT-button in the instrument GUI. The routines check after every image whether the data acquisition has been aborted, *i.e.*, it can take up to a full integration time before the macro is actually aborted. During data acquisition, the macros should only be terminated using the ABORT-button; Ctrl-C would possibly cause instrumentation problems. Outside a MIDAS procedure, Ctrl-C can be used to abort the current MIDAS command. This might, however, close your MIDAS session and also close the X-terminal. In this case just launch the session again. If MIDAS complains about an already open session proceed with “yes”.

Documentation of all MIDAS commands is given in the help-GUI in the quicklook desktop. Furthermore the ESO web pages provide an introduction to MIDAS. Please refer to

http://www.eso.org/projects/esomidas/doc/user/98NOV/vola/index.html.

Sounds

Some utilities run for a relatively long time. In order to alarm the observer, if an action has to be taken or if something went wrong sounds are played. Please make sure that the speakers are connected properly to `o2klinux`. The following events are signalled by sounds:

- End of a procedure — gong
- User is prompted — doorbell
- Result is displayed (no immediate action necessary) — whistle
- Abort or error — crash
- Input error — sorrydave

If you want to test the sounds please use the shell command

```
auplay /disk-a/staff/GEIRS/SOUNDS/sound_name.au
```

where *`sound_name`* is to be substituted by the above given names.

Please note that the sounds described above are independent of the sounds issued by GEIRS (see upper right in Figure 36 for the window where to control GEIRS sounds).

Most of these utilities have been prepared by René Faßbender in the context of his diploma thesis.

13.1. *Calibration series*

Function call

o2k/calser [ident] = [time] [coadds] [number] [spacing] [save] [reset]

Remark: "o2k/calser" is an OMEGA2000-context command which calls the routine "calibration_series.prg". The routine can also be called without the context command in the following way: @@ O2K_UTIL:/obs_macros/calibration_series

Defaults

ident	no default	use quotes if containing blanks
time	no default	
coadds	1	one image per read cycle
number	5	take 5 read cycles
spacing	lin	exposure times increase linearly
save	s	save all images of a read-cycle as single frames
reset	no_reset	historical option to avoid detector problems. Use default, unless you know what you are doing.

Examples

- **o2k/calser** dark = 300

  Takes 5 dark exposures with exposure times from minimum available time to a maximum of 300sec. The exposure time increases linearly from exposure to exposure.

- **o2k/calser** "flat H" = 2,10 3 ? log

  Flatfield with 3 integrations added in memory. Five images taken. Logarithmically increasing exposure times between 2 and 10 sec.

- **o2k/calser** help

  Shows help text.

Parameter explanation

External (command line) parameters

P1 = identifier

P2 = =

P3 = time or min_time,max_time

Longest exposure time in series [sec], starting with 0 or
minimum and maximum integration time, between which exposures will be taken.

P4 = coadds

number of exposures to be taken in a read-cycle

`P5 = number`

Number of images (read-cycles) to be taken. This defines the intervals in exposure time between minimum and maximum.

`P6 = spacing`

Exposure times may be increased linearly [lin], logarithmically [log] or not at all [zero]. In the latter case the exposure time is set to [time].

`P7 = save mode`

The images of a read-cycle are saved either as single files (s) or integrated (i) in memory and saved as one file.

`P8 = reset`

Before exposure time is changed a reset is performed in that sense that the exposure time is set to the minimum time, then two images are read out without saving them. Then the exposure time is set to the desired value. This should help eliminate the fifo-overflow problem, now hopefully solved. `no_reset` suppresses this feature.

Functionality

The desired filter and the read-out mode have to be selected manually before this routine is called. The exposure times for the number of specified images is calculated as follows: The interval between minimum and maximum time is divided (linearly or logarithmically) into (n – 1) segments. If the exposure time is less than the minimum time allowed by the read-out mode, it is set to this minimum time. Therefore, if the exposure times are such, that also further images are still below the minimum integration time, several images will result with minimum exposure time. If no increase in exposure time is selected [zero] the exposure time is set to the maximum time specified in parameter 3.

Note about darks

We found out in September 2004 that the filter wheel is not absolutely light tight. So in taking darks you should put the J_low filter into wheel 1, blank in wheel 2 and *e.g.* H in wheel 3.

13.2. *Dome flats*

Function Call

`o2k/domeflats` `ident = lamp time coadd number save saturation`

Images are taken at the current telescope position. The appropriate telescope position is *t* = 0h and δ = -30°. Put the dome at azimuth 90° (*i.e.* do not use the flatfield screen!). The files will have the names specified in the instrument GUI. Filter and read-out mode have to be set manually before call.

Defaults

identifier	no default
lamp	no default, has to be 1 to 5. In case of 5 also the level is needed
time	no default
coadds	1
images	1
save	i(ntegrated)
saturation	30000

Examples

`o2k/domeflats` `“dome H” = 5,1 3`

Takes one image in a single exposure with lamp 5 at level 1Watt. Exposure time is 3 sec.

`o2k/domeflats` `“dome H” = 5,1 3 5`

Same as above but 5 images are added up in memory and saved as an integrated image.

`o2k/domeflats help`

Help text.

Parameters

external

`P1 ident`

Object name for the FITS header. Use quotes if text contains blanks.

`P2 =`

`P3 lamp`

The lamps are numbered 1 to 5 (decreasing brightness). Only lamp 5 can be adjusted in its level from 1 to 10 W. Give level in addition to lamp number in this case like 5,1.

`P4 integration time`

The exposure of a single frame in seconds.

`P5 coadds`

Number of exposure repetitions in one read cycle

P6 `images`

Number of read cycles to be executed

P7 `save mode`

If integrated (i) is selected, all exposures taken in a single read-cycle (coadds) are summed up in memory and stored as a single file on disk. In single (s) mode, the exposures are stored individually.

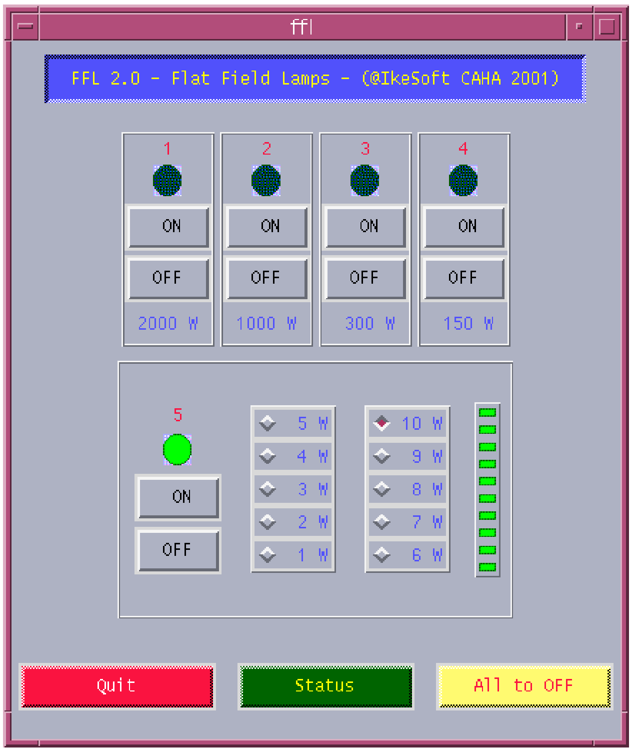
P8 `saturation`

The saturation level, above which the procedure will be aborted.

13.2.1. Operating the flatfield lamps

The lamps are permanently mounted on the southern telescope base. They are either operated via the GUI `ffl` or via shell commands.

To launch the GUI, type `ffl &` in any xterminal on the fire35. The GUI will pop up:



If you want to operate the lamps from shell commands (as is the case with the above command `o2k/domeflats` in MIDAS), the GUI has to be shut down via the QUIT button first!

Shell commands:	`flats ALLOFF`	turn all lamps off
	`flats L`*`i`* `on`	turn on lamp *`i`* (*`i`* = 1 … 4)
	`flats L5 on` *`lev`*	turn on lamp 5 with level *`lev`* (*`lev`* = 0 … 9)
	`flats L`*`i`* `off`	turn off lamp *`i`*

13.3. *Taking twilight flats*

Function call

o2k/skyflats [ident] [level] [coadds] [number] [offsets] [check] [saturation] [time]

Remark: "o2k/skyflats" is an OMEGA2000-context command which calls the routine "skyflats.prg". The routine can also be called without the context command in the following way: @@ O2K_UTIL:/obs_macros/skyflats.

Defaults

ident	no default	
level	20000	maximum level in a single exposure to be 20000cts.
coadds	2	exposures are added up in memory to a single image
number	5	take 5 images
offsets	0,30	offset telescope between read-cycles (not exposures!) by 30" in DEC, no offset in RA.
check	check	
saturation	30000,45000	saturation and monitoring limit
time	dusk	

Examples

- **o2k/skyflats** "dusk H"

  Take 5 time 2 exposures with ~20000cts/pixel each saved as 5 separate images in disk. Offset the telescope between images, *i.e.* after 5 exposures, by 30" in declination only.

- **o2k/skyflats** "dusk H" offsets=60,60

  Same as above but with offsets RA = 60" and DEC = 60"

- **o2k/skyflats** help

  Shows help text.

Parameter explanation

External (command line) parameters

P1 = ident

Identifier for the images to be taken.

P2 = level

Desired count level for a single exposure in counts/pixel.

P3 = coadds

Number of exposures to be taken in a read-cycle.

`P4 = number`

Number of read-cycles to be taken. This is also the number of different positions on the sky used for the flatfields.

`P5 = offsets [RA_offset,DEC_offset]`

Telescope offsets to be executed between read-cycles (not exposures!).

`P6 = check`

Determines whether the exposure level is checked in a test exposure after each read-cycle. Use `no_check` to suppress checking.

`P7  = saturation, monitoring_limit`

Saturation level of single exposure and maximum level until which the level monitoring should be executed.

`P8  = time of day (dusk or dawn)`

Specifies whether evening or morning flats are taken. This determines the behaviour of the level monitoring.

Functionality

The filter and read-out mode have to be selected manually before calling this routine. The procedure takes test exposures with the minimum available integration time to calculate the time needed to reach the desired level. Detailed behaviour depends on the time of the day:

<u>Evening:</u> If the exposure level in the test exposure is above the specified saturation level no images are taken. The procedure is aborted if the level is above the monitoring level, as the sky is still too bright. If it is between the saturation level and the monitoring level it loops back and takes another test exposure. This is done until the level is below the saturation level. Then images are taken with an exposure time scaled on the basis of the last test exposure to reach the desired level. If the resulting exposure time turns out to be longer than 60sec, the user is prompted for confirmation before the exposures are started.

<u>Morning:</u> If the exposure level is above saturation, the procedure is aborted. If the resulting exposure time is longer than 60 sec, the user is prompted for an exposure time, when taking of images should be started. Level monitoring is then continued until this limit is reached. Then the images are taken. Should the level reach the saturation limit in the shortest integration time available, the procedure is terminated.

If check option is used, a test exposure is taken after each read-cycle and the exposure time is adjusted accordingly. This is the default.

13.4. *Focus test*

For the focus tests we strongly recommend to use the focus fields provided in Appendix 7 on page 125. These have been tested and work fine in most cases. Problems were encountered for extremely good seeing and/or some filters in the K-band range (narrow band, K itself) due to the high background. We suggest that you use the H-filter for focusing. The focus will automatically be adjusted if you select another filter using the focus offsets measured under good seeing conditions.

Function call

o2k/focus [root] [start_index,master] [focus,step] [ima_number] [itime_total,single] [action_flag] [object_number] [boxsize]

Remark: "o2k/focus" is an OMEGA2000-context command which calls the routine "omega_focus.prg". The focus routine can also be called without the context command in the following way: @@ O2K_UTIL:/obs_macros/Focus/omega_focus

Defaults

root = automatic	take name from GUI
	(start_index = 0001 only if not automatic)
focus = no default	prompt for estimated focus and step size=200
number = 9	take 9 images
itime = 20,2	20 secs total integration, 2 secs single integration
action = 0,1	take, analyze, and move focus ; show all graphics
objects = 40	search about 40 objects
boxsize = 18	total boxsize in arcsecs around objects for analysis

Examples

- **o2k/focus** focus=23500,200 number=7 itime=10,1

  Use 7 different focus positions centered around 23500 microns with offsets of 200 microns. The total integration time per image is 10 seconds, which consist of 10 co-added 1 second exposures. The image name in the GUI is used for the filenames.

- **o2k/focus** foc_H 4 24000,200 7 20,2 1

  Use the seven images with names foc_H0004.fits – foc_H0010.fits for the focus analysis only. The best estimated focus was 24000 microns. The integration time is in this instance only used to compute a saturation cutoff for the object selection.

- **o2k/focus** help

Shows help text.

- **o2k/focus** prompt

  Inquires all parameters interactively.

Parameter explanation

External (command line) parameters

P1 = root

Root name of all relevant images. The full image name is expected to consist of the root and a 4 digit index, *e.g.*, foc_H0001.fits with root=foc_H. The index P2 must result in unique filenames if new images are taken; otherwise existing files will be overwritten! It is thus not recommended to specify the root for taking images!

If no root is specified, the current image name in the instrument GUI is used as filename. This mode is only possible if new focus test exposures are taken.

P2 = index(,master)

Index of the first image, i.e., the image with the lowest focus setting. Optional index for master (see details below).

P3 = focus [estimated focus, step size]

Best estimated focus in microns and focus offsets between two test exposures in microns.

P4 = number

Total number of images for the focus analysis. The input has to be a odd number larger than 3. If an even number is specified, it will be converted to the next odd number.

P5 = itime [total integration time per image, single integration time]

Integration times in seconds. The first number specifies the total integration time per image, the second one the integration per single exposure, which will be co-added to yield one integrated image.

P6 = action [action_flag, graphics_output]

Two integers that specify the action taken and the feedback to the user:

action_flag = 0 → all actions carried out: image taking, analysis, best focus adjustment
1 → do only image analysis; no instrument and telescope commands sent
2 → analyze images and adjust focus to the best setting
3 → take images and analyze

graphics_output = 0 → show only final graph
1 → show all graphs including the selection process

`P7 = objects`

Approximate number of objects to be searched for and analyzed. The default value of 40 is appropriate for fields with enough stars. For sparse fields, the parameter may be set to lower values.

`P8 = boxsize`

Total boxsize in arcseconds around objects for the objects analysis. The default value should be working in most cases.

Internal

The routine contains three internal parameters which are defined at the beginning of the routine:

Pixel saturation: Maximum count level per single image exposure in the linear detector regime.

Minimum and maximum galaxy cutoff parameters: The empirical FWHM cutoff parameters for the final object selection step.

Trouble shooting

The standard focus test involves an automatic object search on the central (master) image, supposed to be approximately in focus. In case of exceptionally good seeing or high background (K-band) this search may fail and you will not get a valid focus measure. To help the software find objects under good seeing conditions it is possible to shift the master frame by specifying the second part of parameter P2, giving the index number of the alternative master.

Example: root = F index = 271 (i.e. images F0271 … F0279 are the focus test). Default master is F0275. By giving P2 = 271,273 you select image F0273 as the master. All the rest remains as before.

```
o2k/focus F 271,273 23800,200 9 20,2 1,1
```

will re-analyse the focus series F0271…279 already taken with the master being F0273.

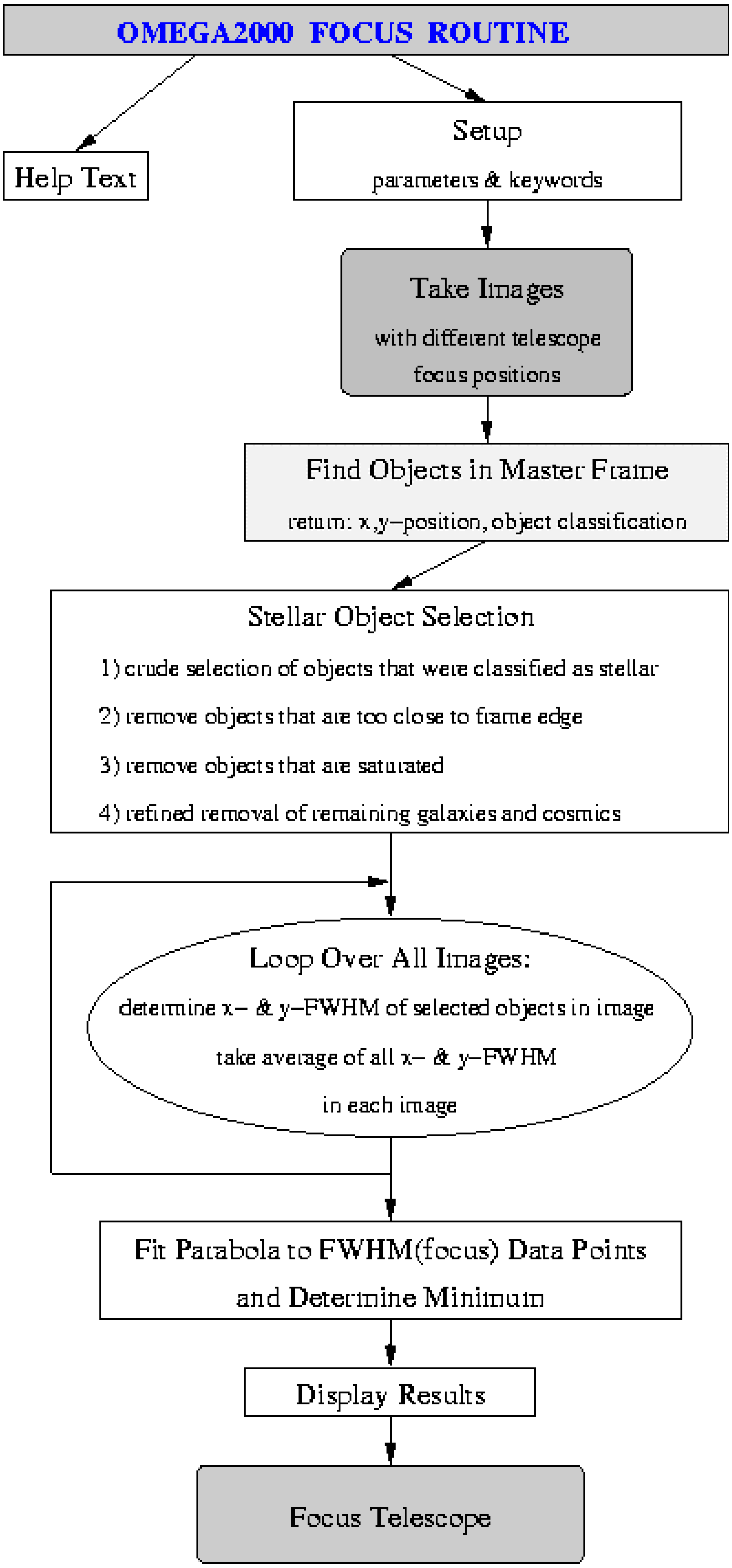
In case you experience problems (no objects found) and do not want to rely on the focus offsets you may have to evaluate the focus test manually. Proceed as follows:

- Flatfield the focus exposures
- Select one object not saturated, if possible, in the optimum focus image
- Use `center/gauss` to measure its half-width for each focus test
- Plot the FWHM as a function of focus position
- Fit a parabola to the data
- Determine the minimum and thus optimum focus

The MIDAS command `regression/table` will be helpful, if you put your measurements into a MIDAS table with the MIDAS table editor (`edit/tab`).

Functionality

The following flow chart demonstrates the principal structure of the focus routine:



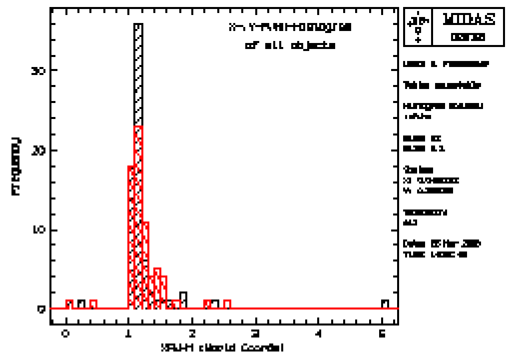
Before the parabola is fitted the deviations between FWHM in X and Y are analysed. Points who differ in FWHM between the two axis by more than 2.5σ of the difference distribution are discarded in the fit.

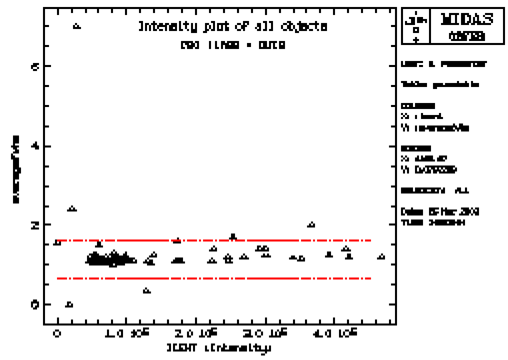
Graphics output

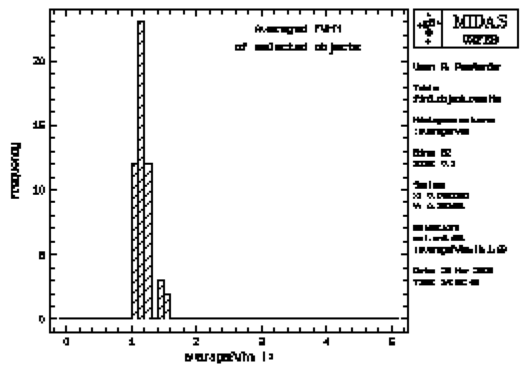
A total of 4 graphs is plotted during the object analysis process:

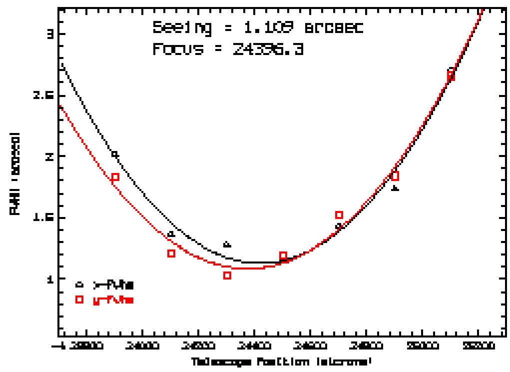
1. A x- and y-FWHM histogram of all found objects
2. An FWHM vs. intensity plot with the used cutoffs
3. The FWHM histogram of the objects selected
4. The final plot with the x- and y-focus parabola and values for the best focus and the seeing. This plot is automatically saved as .ps file, with the filename corresponding to the name of the masterframe.

The first three graphs may be suppressed be setting the graphics_output flag to 0.









13.5. *Tip-Tilt Determination*

The tip-tilt determination routine is based on an old version of the omega_focus routine and needs some preparation steps before it can be properly used. Since the detector tip-tilt is only determined a few times and is not a general user task, the routine is not optimized for user-friendliness. The different steps for obtaining a local focus mask are:

Preparation

- The tilt-routine does not take images. Focus images have to be taken with the normal o-mega focus routine described in Section 13.1.
- The .fits focus images have to be converted into `.bdf` format with filenames consisting of a 5 character root name and a 3 digit index, *e.g.*, `focus001.bdf` or `foc_K097.bdf`. The relevant images have to have consecutive indices. The conversion can be done be editing the file: `$O2K_UTIL/obs_macros/Tilt/make_bdf.prg`.
- The internal parameters for pixel saturation and the stellar cutoff can be adjusted to optimize the output quality.

Function Call

The function call

```
o2k/tilt
```

will prompt the relevant parameters: estimated focus value, number of images, step size, name of first image (in the above format), name of master image = image with the estimated focus (in the above name format), number of objects, and box size.

Note: The use of the default value for box size is suggested (it is specified in pixels). The default for the number of objects is 200, which is the maximum the search routine can handle.

Example

```
o2k/tilt
```

typical inputs at the prompt would be:

24000	→ estimated focus
7 or 9	→ number of images
200	→ step size
focus001	→ name of first image with full name `focus001.bdf`
focus004	→ name of masterframe if 7 images were used
default	→ object number
default	→ box size

- The results are stored in the output frame tilt_frame.bdf, which contains the local focus deviation compared to the average focus over the field-of-view. The average is set to the arbitrary value 100,000, the deviations are given in microns. Appropriate cuts are thus [99900,100100].

- If focus series at different telescope positions exist, i.e., the stars are at different detector locations, the results can be combined into one output frame with a larger number of data points. This can be achieved be editing the file: `$O2K_UTIL/obs_macros/Tilt/master_tilt.prg`, which combines the results from two tilt measurements. Before it can be used a master tilt frame, *e.g.*, `master_tilt.bdf`, has to be created.

Functionality

The tilt routine is determining the local focus position according to the algorithm described in 1) (without the telescope and instrument parts). The local deviation of the focus from the average over the field-of-view is plotted in an output frame.

13.6. *Taking dithered science frames*

Two different observing macros are provided: One for dithered observations of "sparse" fields, with sky determination from the science frames, and a second macro for alternate observations of an extended object and a designated sky field.

13.6.1. Survey observations

Function Call

```
o2k/dither icatalog itime=[tot_pointing,tot_single,single]
           object start_pos,tel_pos pointing offsets autoguide
```

Remark: The actual routine is called "`dither_pointing.prg`" and can also be called by:

```
@@ O2K_UTIL:/obs_macros/dither_pointing
```

Defaults

icatalog	no default
itime	no default
object_identitfier	no default
start_pos = 1,PREV	start at first dither position, telescope at n-1
pointing = 1	pointing identification number for header
offsets = 0	use pixel integer offsets for the dither pattern
autoguide = no	do not correct dither offsets for telescope drifts.

Examples

```
o2k/dither QSO_H 3600,30,5 "quasar at z=1.5" ? 4
```

Take 5 second exposures and add them up in memory to 30 second integrated images. The total integration time is 3600 seconds. The dither pattern starts at the default start position, the descriptor POINT_NO will contain the value 4. The name of the image catalogue created is "QSO_H.cat", the descriptor IDENT of all images will contain "quasar at z=1.5".

```
o2k/dither icat=field_A itime=1000,20,2 object="field A"
           start_pos=35,AQ   pointing=8 offsets=1
```

Take 2 second exposures and add them up in memory to 20 second integrated images. The total integration time is 1000 seconds. The dither pattern continues at position 35, with non-integer dither offsets. Telescope is at the acquisition position. The descriptor POINT_NO will contain the value 8. The name of the image catalogue created is "field_A.cat", the descriptor IDENT of all images will contain "field A".

```
o2k/dither help
```

Help text.

Parameters

external

`P1 = icatalog`

Name of image catalogue that contains a list of all taken images. The name of the image catalogue is automatically passed on to the pipeline and can be used for online data reduction. If no online or further pipeline reduction is desired, this parameter is just a dummy. For online reductions, the *icatalog* parameter should by specified with distinct names to prevent pipeline reduction of the wrong data set.

`P2 = itime [tot_pointing,tot_single,single]`

Integration times in seconds.

tot_pointing is the total integration time for the pointing. This parameter determines the final limiting magnitude of the pointing. *Tot_pointing/tot_single* images are take at different dither positions.

tot_single is the time for one integrated image, which is equivalent to the integration time at a one dither position. *Tot_single/single* exposures are added up in memory before the final single image with an integration time of *tot_single*-seconds is saved on disk.

Single is the a single exposure integration time. This parameter is to be optimized for each filter to allow background limited observations while being within the linear detector regime.

Note: To prevent truncation errors when calculating the number of repetitions, *tot_pointing* should be a multiple *of tot_single*, and *tot_single* should be a multiple of *single*.

`P3 = object_identifier`

Character string for the IDENT descriptor. If blanks are contained, the string should be enclosed in " ".

`P4 = start_pos,tel_pos`

Starting position of the dither sequence. This parameter allows the continuation of the dither pattern at a specified position after an interruption. As a default the telescope is expected to be in the (`start_pos-1`)th position (`tel_pos=PREV`), from where the dither pattern is continued with the next position. If the current telescope position is the field acquisition position (`tel_pos=AQ`) then the telescope if offset to position `start_pos-1` before nominal operation (=offset to the desired starting position) is resumed. This is convenient, if the previous sequence was aborted and the field had to acquisitioned again.

`P5 = pointing`

Identification integer for the descriptor POINT_NO. Can be used for easier data identification.

`P6 = offsets`

Flag for dither offset mode.

offsets=0 → the offsets will integer multiples of the pixel scale
offsets=1 → offsets in units of 1/3 of a pixel are used for the dither pattern. This facilitates the use of drizzle to obtain "super"-resolution in case of very good seeing.
offset=`my_foffsets`
→ the offsets are specified in a file with this `myoffsets.dith`. This file is a plain ASCII-file with ΔX,ΔY in arcsec per line (no blanks allowed). The first line is a comment and exactly 20 offsets are required. The offsets are relative to the previous position. The standard repetition offsets (see below) are used also in this case. This file has to be located in the current path.

The standard mode should be integer offsets because it facilitates a later summation of several images by appropriate xy-shifting.

`P7 = autoguide (y/n)`

internal

The keyword **file_path** defined as the first keyword in the PRG contains the path information for the pipeline auxiliary files. In online-mode, the pipeline searches this path for all relevant information.

Dither Pattern

The standard dither pattern is shown in Figure 41 below. The actual pattern consist of 20 different positions with typical relative offsets of 20-30 arcsecs. After 20 images, the telescope is moved back to the origin and this origin is then shifted according to the repetition pattern (Figure 42) before the basic pattern is started again. This way, 400 different positions are defined (Figure 43), after which the pattern starts back at position 1. This also holds, if the dither pattern is specified by a user-supplied file.

Note: The positions of the primary dither pattern are all within a square of ±18 arcsecs from the origin, the shifted origins for the repetition pattern are within a square ±5.5 arcsecs from the origin. Thus, the maximal "waste" area at the edges, where not all images overlap, is 23.5 arcsecs on each side. The effective central observing area, where all images overlap, is a minimum of 14.5x14.5 arcminutes for any number of dither positions used. Please note that the "waste" area is not really lost. If the same dither pattern is used for all pointings one may regard the whole mosaic as subjected to this dither pattern. This, however, complicates data reduction considerably.

Autoguiding

To initiate autoguiding, an acquisition frame is to be taken manually. Using `o2k/offset` a reference star is defined, whose position will then be checked after each dither position. Then `o2k/dither` is started and each dither offset will be corrected for any positional discrepancies (telescope drift…) if `auto=yes` is given. If the reference star is lost (telescope glitch) the user will be prompted to decide if observing is to be continued without autoguiding.

Autoguide is governed by a file containing the position of the reference star, which is created by `o2k/offset`, once the offset had been applied automatically (not by hand) by `o2k/offset`. Make sure this file is up-to-date.

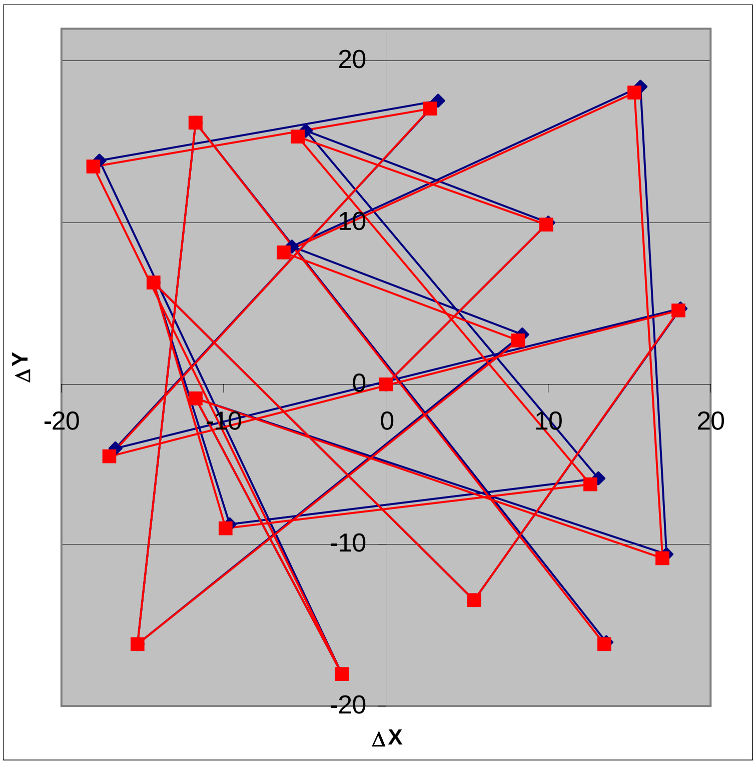


Figure 41: Standard dither pattern with 20 positions for integer pixel offset (red) and fractional pixel offsets (blue).

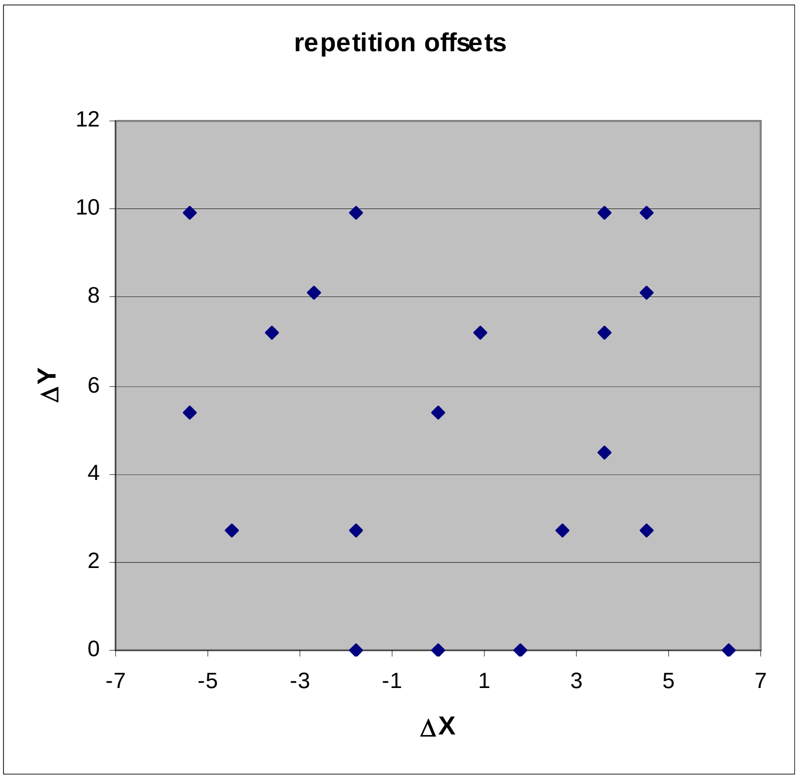


Figure 42: Offsets for the repetition patter.

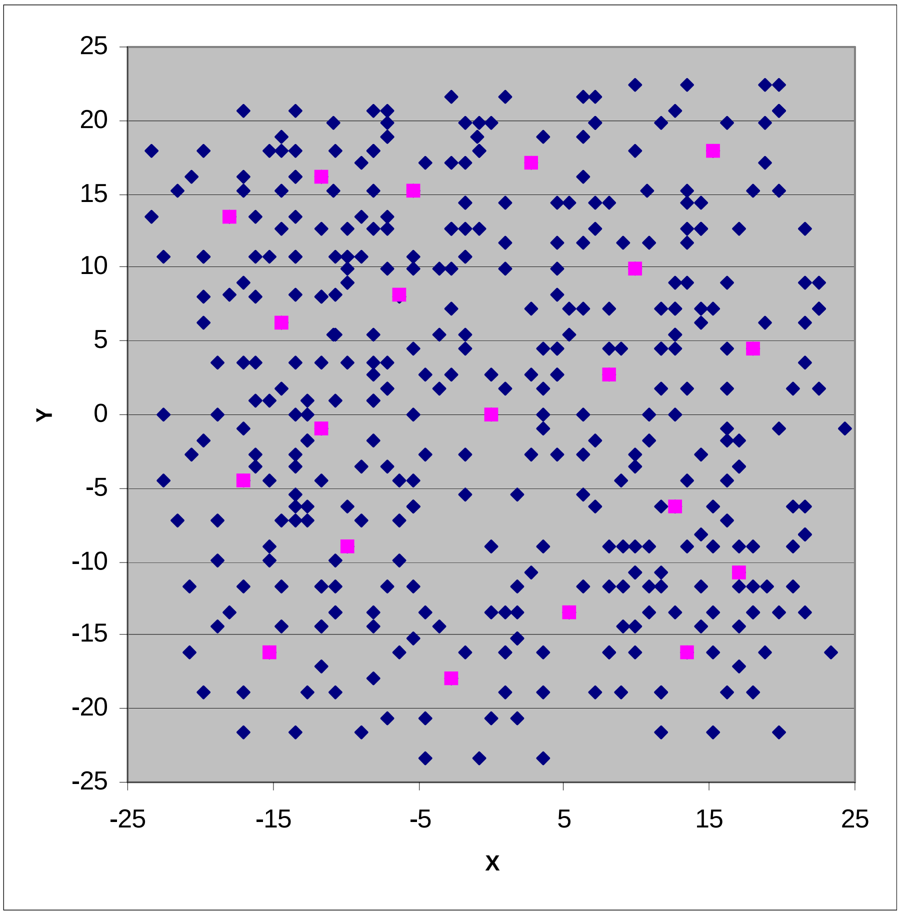


Figure 43: Telescope positions for a complete cycle of 400 independent dither positions. Basic pattern is shown in pink.

Comments

- The observing macro prepares the online pipeline data reduction. The name and path of the image catalogue and the integration time are stored in auxiliary files, which can be accessed by the pipeline. The image catalogue is updated with the name and path of the latest image after every integration.
- With each new telescope movement the time, the offset and the dither number are written into a log file `tel_pos_{date}.log` in the current directory. The date in the file name is the date and time the MIDAS procedure was started.

13.6.2. Extended objects

Function Call

```
o2k/sky_point icatalog
   itime=[tot_pointing,tot_single,single,tot_single_sky]
   move direction object  start_pos pointing offsets
```

Remark: The actual routine called is "`sky_pointing.prg`" and this may also be called by: `@@ O2K_UTIL:/obs_macros/sky_pointing`

Defaults

icatalog	no default
itime	no default
move = 30	sky position is at a distance of 30 arcmin from object
direction = all	use 8 different sky positions around object
object_identitfier	no default
start_pos = 1	start at first dither position
pointing = 1	pointing identification number for header
offsets = 0	use pixel integer offsets for the dither pattern

Examples

```
o2k/sky_point M51 3600,30,5 20 N "M51 in J" ? 2
```

Take 5 second exposures and add them up in memory to 30 second integrated images. The total integration time for the object is 3600 seconds. The integration time for the sky observations is not specified, thus the same values as for the object are used. The sky images are taken 20 arcmin North of the object. The dither pattern starts at the default start position, the descriptor POINT_NO will contain the value 2. The name of the image catalogue created is "M51.cat", the descriptor IDENT of all images will contain "M51 in J".

```
o2k/sky_point icat=field_A itime=1000,20,2,10 move=10
      direction=ALL object="field A" start_pos=35  pointing=8
      offsets=1
```

Take 2 second exposures and add them up in memory to 20 second integrated images. The total integration time for the object is 1000 seconds. The total integration time for a single sky image is set to 10 seconds, thus five 2-second exposures are co-added in memory for the sky. The sky images are taken 10 arcmin away from the object at 8 different positions. The dither pattern starts at position 35 with non-integer pixel offsets, the descriptor POINT_NO will contain the value 8. The name of the image catalogue created is "field_A.cat", the descriptor IDENT of all images will contain "field A".

`o2k/sky_point help`

Help text

Parameters

external

Compared to the macro for normal observations, three additional parameters have to be specified for observations of extended objects: the distance and direction of the designated sky field from the object and the integration time for a single sky exposure.

`P1 = icatalog`

Name of image catalogue that contains a list of all taken images. The name of the image catalogue is automatically passed on to the pipeline and can be used for online data reduction. If no online or further pipeline reduction is desired, this parameter is just a dummy. For online reductions, the *icatalog* parameter should by specified with distinct names to prevent pipeline reduction of the wrong data set.

`P2 = itime [tot_pointing,tot_single,single,tot_single_sky]`

Integration times in seconds.

tot_pointing is the total integration time for the pointing. This parameter determines the final limiting magnitude of the pointing. *Tot_pointing/tot_single* images are take at different dither positions.

tot_single is the time for one integrated image, which is equivalent to the integration time at a one dither position. *Tot_single/single* exposures are added up in memory before the final single image with an integration time of *tot_single*-seconds is saved on disk.

single is the a single exposure integration time. This parameter is to be optimized for each filter to allow background limited observations while being within the linear detector regime.

tot_single_sky is the total integration time for a single integrated sky exposure. If this parameter is omitted, the object integration times will also be used for the sky. The total integration time for sky observations is the fraction *tot_single_sky/ tot_single* of the total object observation time.

Note: To prevent truncation errors when calculating the number of repetitions, *tot_pointing* should be a multiple *of tot_single*, and *tot_single* should be a multiple of *single*. The single exposure time *single* is also used for the sky observations, thus *tot_single_sky* should also be a multiple of *single.*

`P3 = move`

Distance of sky field from object in arcminutes.

`P4 = direction`

Direction from object for the designated sky field. Can be set to N, S, W, E for a designated sky field North, South, West, or East of the object. If set to ALL, 8 different sky positions located around the object at the specified distance are used.

`P5 = object_identifier`

Character string for the IDENT descriptor. If blanks are contained, the string should be enclosed in " ".

`P6 = start_pos`

Start position of the dither sequence. This parameter allows the continuation of the dither pattern at a specified position after an interruption. The telescope is expected to be in the (start_pos-1)th position, from where the dither pattern is continued with the next position.

`P7 = pointing`

Identification integer for the descriptor POINT_NO. Can be used for easier data identification.

`P8 = offsets`

Flag for dither offset mode.

offsets=0 → the offsets will integer multiples of the pixel scale
offsets=1 → non-integer offsets are used for the dither offsets.
offset=`name` → the offsets are specified in a file with this name. This file is a plain ASCII-file with ΔX,ΔY in arcsec per line (no blanks allowed). The first line is a comment and exactly 20 offsets are required. The offsets are relative to the previous position. The standard repetition offsets (see below) are used also in this case. This file has to be located in the current path.

The standard mode should be integer offsets because it facilitates a later summation of several images by appropriate xy-shifting.

internal

The keyword **file_path** defined as the first keyword in the PRG contains the path information for the pipeline auxiliary files. In online-mode, the pipeline searches this path for all relevant information.

Functionality

The dither pattern (for details see Section *Survey observations*) is applied simultaneously to the object and the sky observations. The sky field is specified by a distance from the object and by a direction. If the direction is set to ALL, 8 different sky positions are used: the four shown below, plus the 4 corner positions.

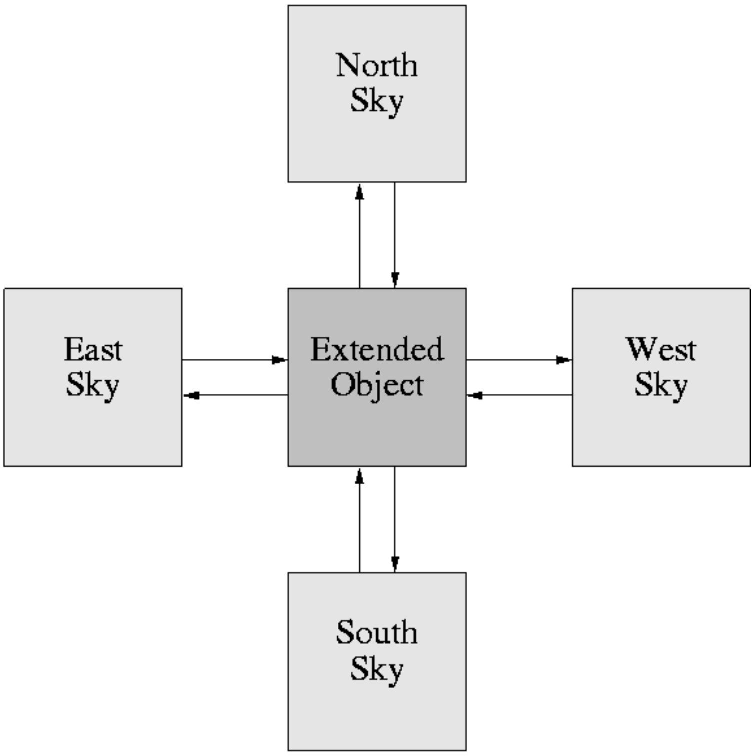


Figure 44: Sky positions for observations of extended objects.

Comments:

- When the observing macro is started, the telescope has to point at the object.
- The observing macro prepares the online pipeline data reduction. The name and path of the image catalogue and the integration time are stored in auxiliary files, which can be accessed by the pipeline. The image catalogue is updated with the name and path of the latest image after every integration.
- With each new telescope movement the time, the offset and the dither number are written into a log file tel_pos_{date}.log in the current directory. The date in the file name is the date and time the MIDAS procedure was started.

13.7. *Measuring the seeing*

```
o2k/seeing  zoom(default)/no_zoom
```

To measure the seeing in a frame proceed as follows:

- Select the quicklook desktop
- Load a flat-fielded image into the display at appropriate scale
- Execute `o2k/seeing`
- Select a region in the display with the crosshair cursor (left mouse click)
  - Region is displayed in zoom window
- Adjust cursor box size in zoom window with arrow keys
  - Hint: hitting 1 ... 9 speeds up cursor movement
- Mark stellar objects with left mouse button
- To go back to the display window click right mouse button in zoom window
- Select next region
- ...
- Exit with right mouse click from display window

The seeing values are appended to file `Seeing.log` in the current directory. The individual measurements for the current call are stored in table seeing.tbl, which is overwritten with each new call to this procedure.

Saturated images are skipped in calculating the seeing.

13.8. *Pixel-accurate alignment of the telescope*

```
o2k/offset dest_X,dest_y
```

To offset the telescope in order to put a star onto a given pixel proceed as follows:

- Select the quicklook desktop
- Load a flat-fielded acquisition image into the display
- `o2k/offset dest_x,dest_y`
  - coordinates are in pixels
- Mark star, whose position is used for alignment, with cursor box
  - This determines the star's centroid via `center/gauss`
- Offset coordinates are displayed
- Execute by giving "`a`" if okay or "`h`" if you need to abort or adjust.
- Check via new acquisition frame (optional)

The telescope pointing is accurate to about 10". If you require higher accuracy you need to calculate the expected position of a reference star in your field *e.g.* from one of the following catalogues and the desired pointing center:

- USNO http://www.nofs.navy.mil/data/fchpix/
- M2000 http://www.obs.u-bordeaux1.fr/public/astro/CSO/equipe/JF/M2000/m2000.htm
- UCAC2 http://ad.usno.navy.mil/ucac/

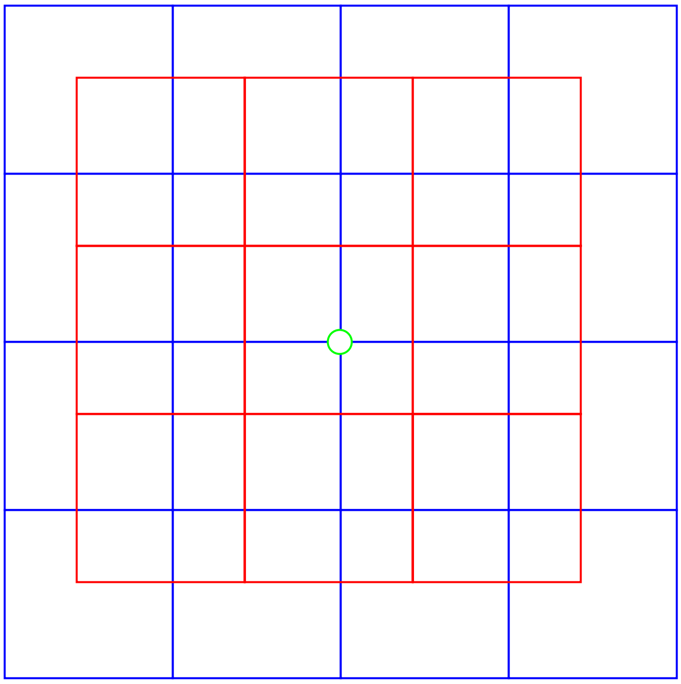
`Due` to the excellent image quality no image distorsion needs to be taken into account.

13.9. *Relative calibration of survey fields*

`o2k/relcal identifier = dit,ndit`

Relative calibration of an OMEGA2000 mosaic of 1 square degree (blue squares in illustration below) by taking 3x3 pointings (red squares) on intersection of the mosaic exposures. Telescope is assumed to be positioned in centre of 4x4 mosaic (O) at start.

Filter and read-out mode have to be set before calling this routine!



13.10. *Determining bad-pixel-mask and dark frame*

The mask for bad pixels and the dark frames (dark signal/pixel/sec) are needed for the pipeline reduction. Both are conveniently obtained from a series of frames with increasing exposure time, the bad-pixel mask from flat fields, the dark images with the blank inserted. Fitting the signal for every pixel as a function of exposure time with a straight line isolates well behaved pixels in the flatfield series (those following a straight line) from the bad ones by analysing a histogram of the slope values found. For the dark series the slope gives the dark signal per second.

This analysis takes the following steps (further documentation see header of prg-file):

- Take the series (either dark or flat)
- Create an image catalogue
  - o for example `create/icat raw XXX*.fits`
- `bias/extrapolation root = frame_list`
  - o for example `bias/extr test = raw:1-4,8-12`
- Analyse the output frames
  - o `root_const.bdf`
  - o `root_slope.bdf`
  - o `root-rms.bdf`

13.11. *Monitoring atmospheric transmission*

```
o2k/transmon  magnitude  filter
```

By comparing the observed counts from a star of known brightness (*e.g.* from the 2MASS catalogue) with the theoretically expected counts one can get a feeling for the amount of atmospheric absorption or at least about variations of it. The acquisition frame is most conveniently used for this purpose, as usually the brightness of the alignment star is known .

The procedure uses a simple approach in that the user places the cursor box around the object of her/his choice and second into the local background. The observed count rate is calculated from the difference of the two (background is scaled by differences in box size). The ratio of measured to expected count rate is written to the log file `Transmission.log` in the current directory.

If the star selected is saturated, the calculation is aborted and an error message is issued.

Currently only the filters J, H, K and Kp are supported.

13.12. *List FITS-files on disk*

To list FITS files on disk, proceed as follows:

- o In any MIDAS session change to the path, where the files are located
  - `ch/dir /disk-b/o2k/DATA…`
- o Create an image catalogue of the FITS files
  - `create/icat raw *.fits`
- o `cat/O2k list_file = frame_list`
  - *e.g.* `cat/o2k day_1 = raw:1-100,150-170` to list files 1 to 100 and 150 to 170 only.
  - This is relatively slow as each file has to be opened and the header information to be retrieved.
- o Output will be an ASCII-file with name `list_file.lis` and the following information (one line per file):

```
file                                                  ident                      <>t NDIT
baffle   filt_1   filt_2   filt_3   read_mode
---------------------------------------------------------------------------------------------
------------------------------------------
O2k_2003-09-11T22_17_01.000.fits / F0001.fits       DQE measurement K-PRIME     0.8    5
NO/OUT   OPEN     OPEN     K-PRIME  double.corr.read
O2k_2003-09-11T22_17_22.000.fits / F0002.fits       DQE measurement K-PRIME     0.8    5
NO/OUT   OPEN     OPEN     K-PRIME  double.corr.read
O2k_2003-09-11T22_17_39.000.fits / F0003.fits       DQE measurement K-PRIME     0.8    5
NO/OUT   OPEN     OPEN     K-PRIME  double.corr.read
…
```

13.13. *List FITS-files on tape*

To list a FITS-tape, proceed as follows:

- o Insert tape into drive on `fire35`
- o `cd /disk-a/o2k/tape_listings`
- o `$PM/fitslist`

Answer the questions and give `OMEGA2k.format` as format file. Please delete the listings you created there.

14. Online data reduction pipeline

General Remarks

- The OMEGA2000 pipeline is a MIDAS application program written in C, which is called from a MIDAS procedures. Thus, an active MIDAS session is required and the context "omega2k.ctx" has to be set for the definition of the utility short-cut commands *o2k/command*.
- Several pipeline parts use the environment variable **O2K_UTIL** which points to the directory **o2k_utilities**. All paths are defined relative from this top level directory.
- The pipeline was written by René Faßbender. A detailed description is given in his diploma thesis, available as a PDF-file together with this manual.

Function Call

```
o2k/pipeline  [image_cat] [frames] [sky_mode] [sum]
                         [kappa_sum] [cuts] [flags] [flatfiels]
```

Remark:
"`o2k/pipeline`" is an OMEGA2000-context command which calls the routine "`OMEGA_pipeline.prg`". The pipeline can also be called without the context command in the following way: `@@ O2K_UTIL:/pipeline/PRGs/OMEGA_pipeline`

Defaults

icat = automatic	use image catalogue created by current observing macro session
frames = 3	use 3 image on either side of a masterframe for the sky determination, i.e., determine sky from a total of 7 images
mode = 2,5	outlier clipping mode with κ = 5
sum = 5,0,1	[n_average, action_flag, sum_save_flag]. Use 5 images for the sum-reference frame determination; do single image reduction + summation ; write out only final sum frame
kappa_sum = 10	eliminate all cosmics that are above a 10 sigma cutoff
cuts = 2,5	set cuts of reduced images to [median–2*sigma ; median+5*sigma]
flags= 0,1,1	[save , position , screen_output] do not save sky frames ; do full detector calibration at start ; display screen output
flatfield = std_cal_file	use the standard calibration ASCII file to look for the relevant calibration frames

Examples

`o2k/online`

Standard pipeline online mode. No parameters needed. The function has to be called after the observations have started. The image catalog created by the observing utility is used. The sky is determined from 5 frames with the fast median mode. The superimposed images are written to disk after every 7th image. The *kappa_sum* cosmics-clipping parameter is set to 10.

o2k/pipeline `june10_obs 3 2,5 5,0,1 10 2,5 0,1,0 &/disk-a/o2k/cal_file.cal`

Reduce the image catalogue "june10_obs.cat". Use 3 images on either side, i.e., a total of 7 images, for the sky determination in outlier mode (=2), with outlier clipping 5 sigma above the median level. Use 5 images for the reference sum frame, do reduction and summation, and save only the final master sum frame. Remove cosmics that are above a 10 sigma threshold. The cuts for the final frames are set to [median-2sigma,median+5sigma]. The modelled sky will not be saved, all calibrations are done at the beginning, suppress any screen output. Use the ASCII file "/disk-a/o2k/cal_file.cal" to read in the paths and names of the calibration files.

o2k/pipeline `icat=obs_B frames=2 mode=0,2 sum=?,2`

Do only single image reduction of the image catalogue "obs_B.cat". Use the minimum mode, with averaging of the 2 smallest values, and sky determination from 5 frames (=2 on either side). The calibration frames are read in from the default calibration file, according to the filter used.

o2k/pipeline `icat=automatic frames=2 mode=1 sum=9,0,2 kappa_sum=8 flatfield=norm_flat.fits,bpm_std.fits,/disk-a/o2k/dark_frame.fits`

Use the current image catalogue of the ongoing observations. The sky is determined from 2*2+1=5 frames in the fast median mode. The reference image for the summation is computed every 9 images, single image reduction and summation is done, and the final cosmics cleaned sum image as well as the real, uncorrected sum image and the difference image are saved. The cosmics clipping parameter is set to 8*sigma above the median. The flatfield "norm_flat.fits" and the bad pixel mask "bpm_std.fits" are in the local directory, the dark current frame is stored in "/disk-a/o2k/dark_frame.fits".

o2k/pipeline `help`

Shows help text**.**

Parameters

external (command line parameters)

`P1 = image_catalogue`

Name (and path if not local) of image catalogue containing all images to be reduced.

If icat=automatic, the online reduction is activated, i.e., the image catalogue created by the currently running observing macro is used and the data is reduced in real time.

LABEL: **icatalog**=

`P2 = sky_frames`

Number of frames on either side of a master frame for the sky determination. Thus, the total number of frames used for the sky is (2**sky_frames* + 1).

LABEL: **frames**=

`P3 = sky_mode [mode, specifier]`

Mode for the sky determination. 3 different sky modes are available: minimum mode, fast median mode, and the outlier clipping mode. The modes can be specified via an integer flag or via a string identifier. The minimum and outlier mode have a second specifier.

1. **Minimum** mode: *mode=0,n* or *mode=min,n* ; n is an integer specifying how many of the smallest values are averaged. n=1 is the real minimum, n=2 takes the average of the 2 smallest values and so on.
2. **Median** mode: : *mode=1* or *mode=med* . Takes the median of each pixel column.
3. **Outlier clipping** mode : : *mode=2,k* or *mode=out,k ; k* a real number specifiying the clipping threshold as k*sigma above the median. All outliers are clipped off before the median of the remaining values is taken.

LABEL: **mode**=

`P4 = sum_parameters [n_average, action_flag, sum_save_flag]`

Parameters for the summation of single images.

n_average: integer specifying from how many images the reference sum frame is calculated. If the *sum_save_flag* is set to 0, an updated summation image is written to disk every *n_average* images.

action*_flag:* Specifies the data reduction action.
0 = do reduction and summation of all images in image catalogue
1 = do summation only, i.e., the input images are already reduced
2 = do single image reduction only, i.e., the images are not superimposed.

sum*_save_flag:* Specifies what sum images are saved on disk.
0 = every updated sum is written to disk every *n_average* images
1 = only the final master sum is written to disk
2 = the final sum and the real, “dirty” (without cosmics removal) sum and the difference of the two are written to disk.

Naming conventions of the sum images:

sum_*icat*.fits	→ for the cosmics cleaned master sum image
cut_sum_*icat*.fits	→ for the cut out cosmics cleaned sum
ave_*icat*.fits	→ for the real, “dirty” sum image
dif_*icat*.fits	→ for the difference image: ave – sum

If intermediate summation results are saved on disk a prefix index is added (except for first one):

2_sum_*icat*.fits, 3_ sum_*icat*.fits,…
the last of these frames is cut out, *e.g.,* cut_7_ sum_*icat*.fits, and always contains the sum of all images.

LABEL: **sum**=

`P5 = kappa_sum`

Cosmics clipping parameter. All values above (median + *kappa_sum**sigma) are classified as comics and removed. *kappa_sum* is a real number.

LABEL: **kappa_sum**=

`P6 = cuts [min,max]`

Cuts for the final frames. The descriptor LHCUTS is set to [median-*min**sigma , median+*max**sigma].

LABEL: **cuts**=

`P7 = flags [sky_save, calibration_position, screen_output]`

Integer flags

sky_save determines whether the modeled sky is saved or not.

0 = sky is not saved

1 = the sky for each input frame is saved with name: sky_*imagenam*.fits

calibration*_position:* position where flatfielding and calibration takes place.

0 = no calibration is done.

1 = all calibrations (bad pixel correction, dark current subtraction, and flatfield correction) are done at the beginning of the reduction process

2 = do flatfielding at the end of the single image reduction ; bad pixel correction and dark current subtraction are still done at beginning.

screen*_output:* specification of the amount of screen output.

0 = screen output is suppressed, the feedback is only saved in the log-file

1 = the pipeline feedback is displayed on the screen

LABEL: **flags**=

`P8 = calibration frames`

Specification of the calibration frames. The calibration frames (flatfield, bad pixel mask, dark current frame) can be specified in 3 different ways:

1. no *specification (=default)*: the standard calibration ASCII file is used to extract the calibration frames
2. *&/path/filename*: an ASCII calibration file is specified. A filename is indicated by a preceding "&", e.g., flatfield=&/disk-a/o2k/cal_file.cal. For the calibration file format see below.
3. *[flatfield,bad_pixel_mask,dark_current_frame]:* the calibration frames are directly specified. If they are nor located in the local directory, the path has to be specified

LABEL: **flatfield**=

Note: For the dark frame the descriptor ITIME has to specify the integration time.
The flatfield frame has to be normalized to 1.

internal (in PRG)

`OMEGA_pipeline.prg` contains a few internal parameters that are used as defaults and the online mode. The corresponding keywords are specified in Section PIPELINE SETUP:

file_path: Has to contain the same path information as the file_path keyword in the observing macros. The keyword is needed for the online mode to allow communication to the current observing macros.

cal_file: Keyword containing the path and name of the default ASCII calibration file.

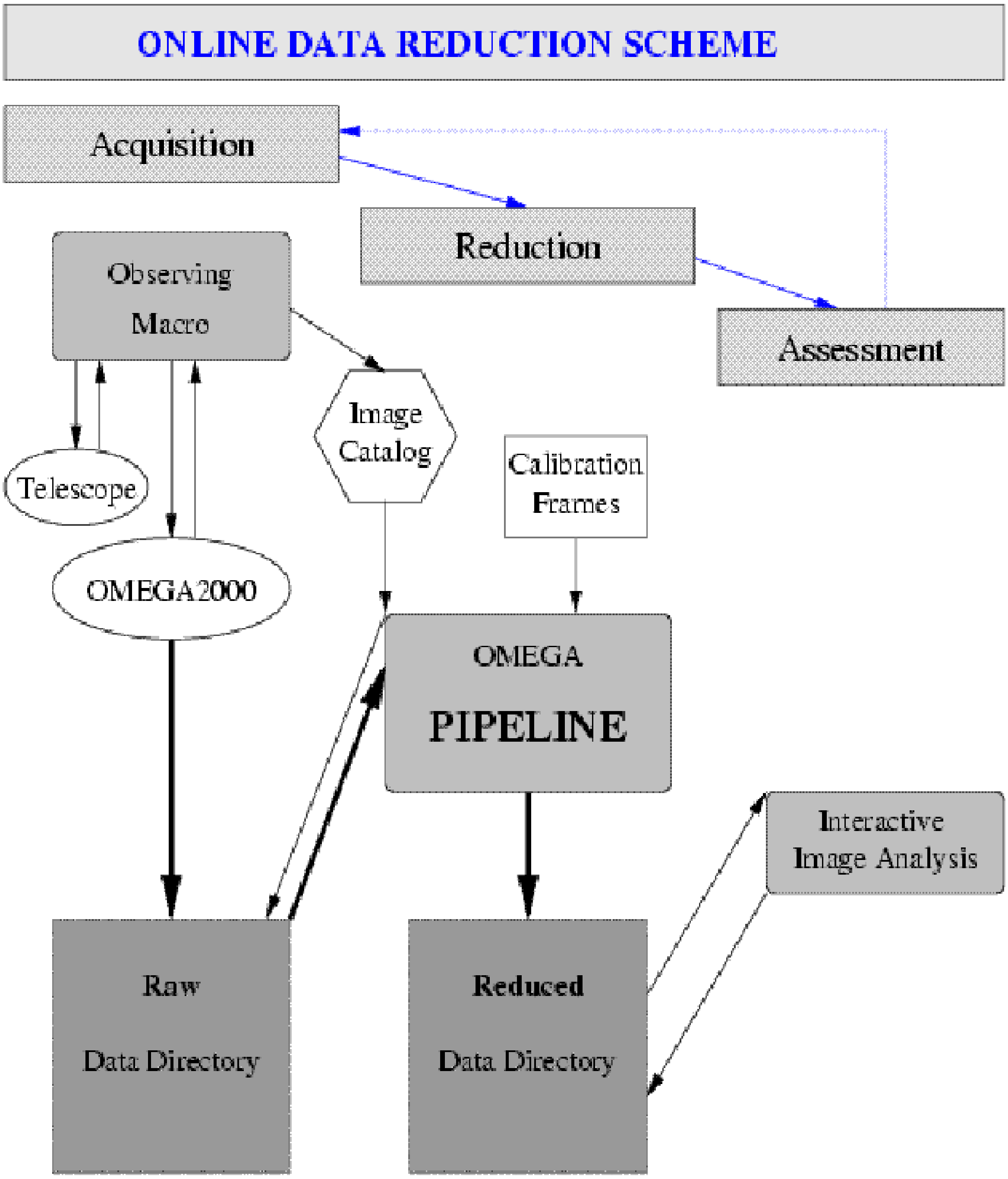
Calibration File

In P8=calibration frames, the name of an ASCII calibration file can be specified (see above). The calibration file has to fulfil the following format conventions:

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
!
!.IDENT  calibration.cal
!
!.AUTHOR Rene Fassbender, MPIA - Heidelberg
!.ENVIRONMENT MIDAS
!.MODULE Calibration file
!.KEYWORDS IR pipeline
!.PURPOSE list name and path of calibration files to be used
!.COMMENTS CONVENTIONS: lines starting with ! are comments.
!
!  Lines with calibration frame information have to start with a standard
!  identifier:
!  BPM for the bad pixel mask, DARK for the dark current frame,
!  and FLAT or the filter name for the different flatfields.
!  If FLAT is present, the specified frame used as flatfield, i.e.,
!  FLAT has priority over FILTER.
!  NOTE: The filter names have to be identical to the specification in
!        the descriptor FILTER.
!  The identifier is followed by " = " and the calibration file name with
!  path information.
!  The names including path should not exceed 80 characters.
!  Specification of flatfields: If the identifier "FLAT = " exists, the
!  given file will be used by the pipeline. If FLAT is not present, the
!  appropriate flatfield is automatically selected using the FILTER name.
!  The FILTER names are expected to be 10 characters long followed by
!  " = ". If the name is shorter, blanks have to fill up the remaining
!  positions.
!  Maximally 100 lines are read in.
!
!.VERSION 1.00  12.06.03
!--------------------------------------------------------------------------

! Bad Pixel Mask
BPM = O2K_UTIL:/pipeline/CAL/bpm_part_blown.fits

! Dark Current Frame
DARK = O2K_UTIL:/pipeline/CAL/dark_current.fits

! Flatfield with priority
!!FLAT = O2K_UTIL:/pipeline/CAL/FLATS/H_flat_best_f.fits

! Flatfields for all filters for automatic selection
!234567891 = path+name
J          = O2K_UTIL:/pipeline/CAL/FLATS/H_flat_best_J.fits
H          = O2K_UTIL:/pipeline/CAL/FLATS/H_flat_best_H.fits
K          = O2K_UTIL:/pipeline/CAL/FLATS/H_flat_best_K.fits
K-PRIME    = O2K_UTIL:/pipeline/CAL/FLATS/H_flat_best_Kpr.fits
NB1237     = O2K_UTIL:/pipeline/CAL/FLATS/H_flat_best.fits
```

14.1.1. Online Mode

Online Reduction Scheme



Pipeline Online Mode

Once an observing macro has been started and has taken at least one image, the pipeline can be started in online mode for the real time data reduction.

There are two ways to run the pipeline in online mode:

1. Use the predefined command:
   `o2k/online` without any parameters

   This command uses the in catalogue information provided by the observing macro and the default calibration file. It is using the fast median method with a total of 5 frames for the sky determination. The intermediate summation results are written to disk every 7th image.

   Note: For this command, the internal PRG parameters (see above) have to be set up properly.

2. Use the normal pipeline command with online specifications:

   The pipeline is started in online mode by setting the image catalogue parameter to "*automatic*".

   `o2k/pipeline` `icat=automatic + other parameters`

   This command also uses the in catalogue information provided by the observing macro, but all other parameters can be specified by the user.

Working with online reduced data

Each new output data frame is created by the pipeline in the following way:

1) Create a plain image without any data
2) Write output data into the new frame
3) Close output image

This implies that the output frames are visible in the reduced data directory after step 1), while the pipeline is still working with the opened frame. The output data frame is only save to use after the frame has been closed in step 3). If the data frame were opened and used by another application between step 1) and 3), serious software trouble would occur. Most likely the pipeline and the other MIDAS session trying to open the unclosed frame would crash.

Thus, a few precautions should be met to be on the save and prevent a session crash:

- The screen output contains the information on what frames have been closed. These images are save to access with other applications.
- The intermediate summation results are saved on disk after every n_th frame. Before a new output frame is created, the old one is closed. Thus, the summation frame with the currently highest index "`*index*_sum_*icat*.fits`" is critical and should not be opened. However, the summation frame with an index 1 lower than the highest can be accessed and opened by other applications without any problems.

Predefined Modes

The following examples state recommended parameter sets for different pipeline applications:

a) Online reduction for normal observations

   `o2k/online` without any parameters
   Uses fast median mode with a total if 5 frames for the sky determination. The intermediate summation result is written to disk every 7th frame.

b) Online reduction for observations of extended objects

o2k/pipeline `icat=automatic frames=2 mode=0,1 sum=7,0,0`

Uses the fast true minimum method for the sky determination with a total of 5 frames. The intermediate summation result is written to disk every 7th object frame.

c) High quality reduction for normal observations

o2k/pipeline `icat=user_specified frames=3 (or 4) mode=2,3 sum=7,0,2`

Uses the outlier clipping method for the sky determination with a total of 7 or 9 frames. Only the final summation frames are written to disk.

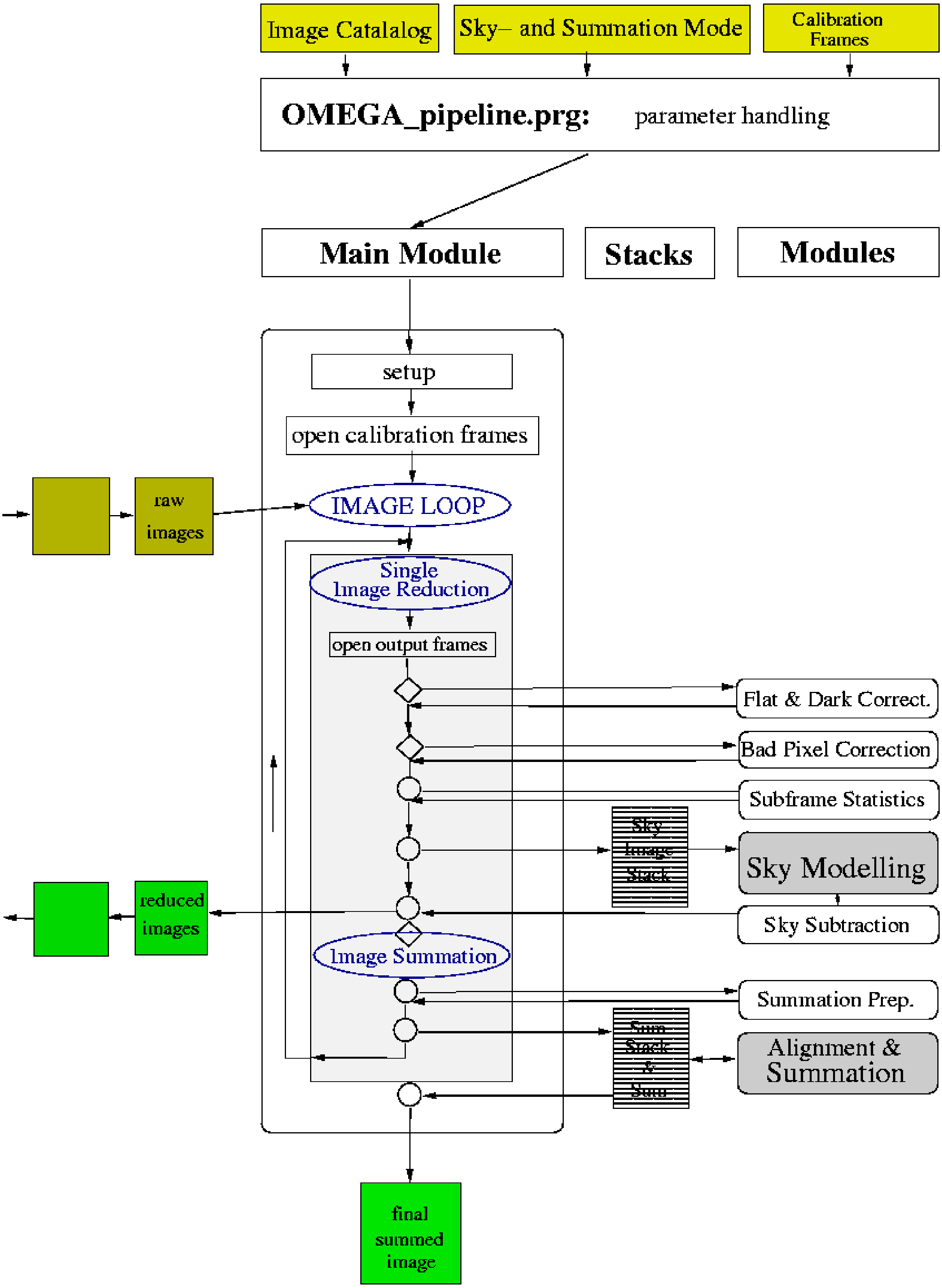
d) Improved quality reduction for observations of extended objects

o2k/pipeline `icat= user_specified frames=3 mode=0,3 sum=7,0,2`

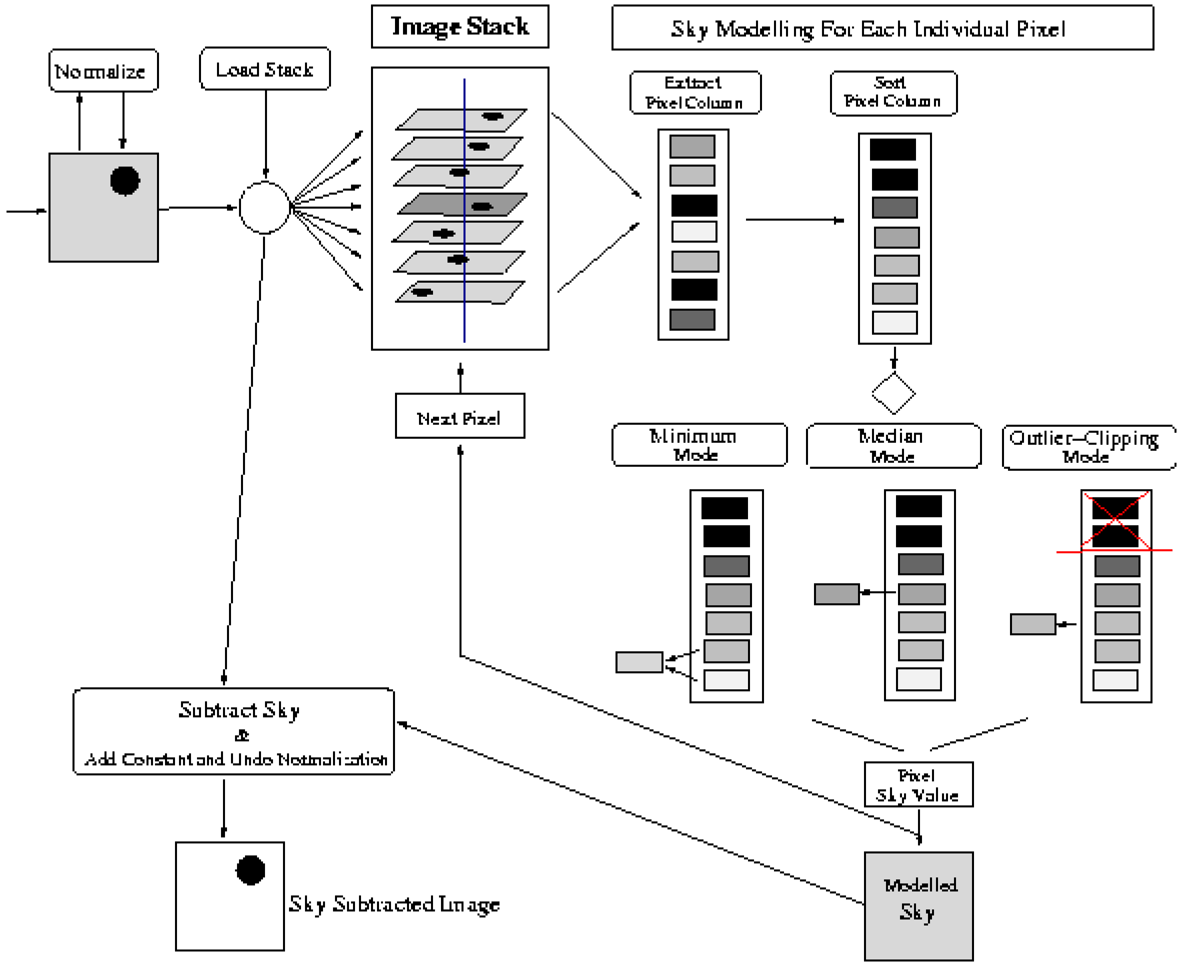
Uses the minimum method with averaging of the 3 smallest values for the sky determination with a total of 7 frames. Only the final summation frames are written to disk.

14.2. *Flowcharts for pipeline*

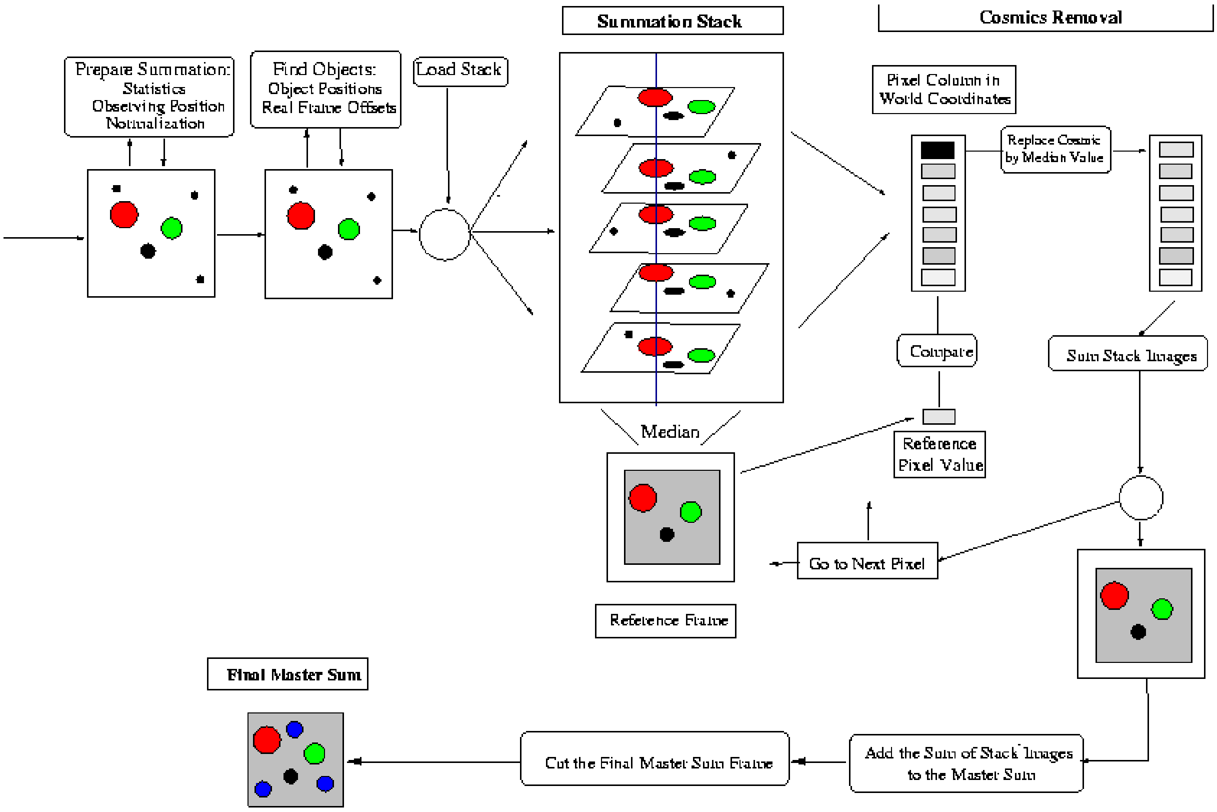
14.2.1. Overview



14.2.2. Sky Determination



14.2.3. Summation of dithered images



14.3. *Examples of pipeline results*

14.3.1. Images taken with o2k/dither

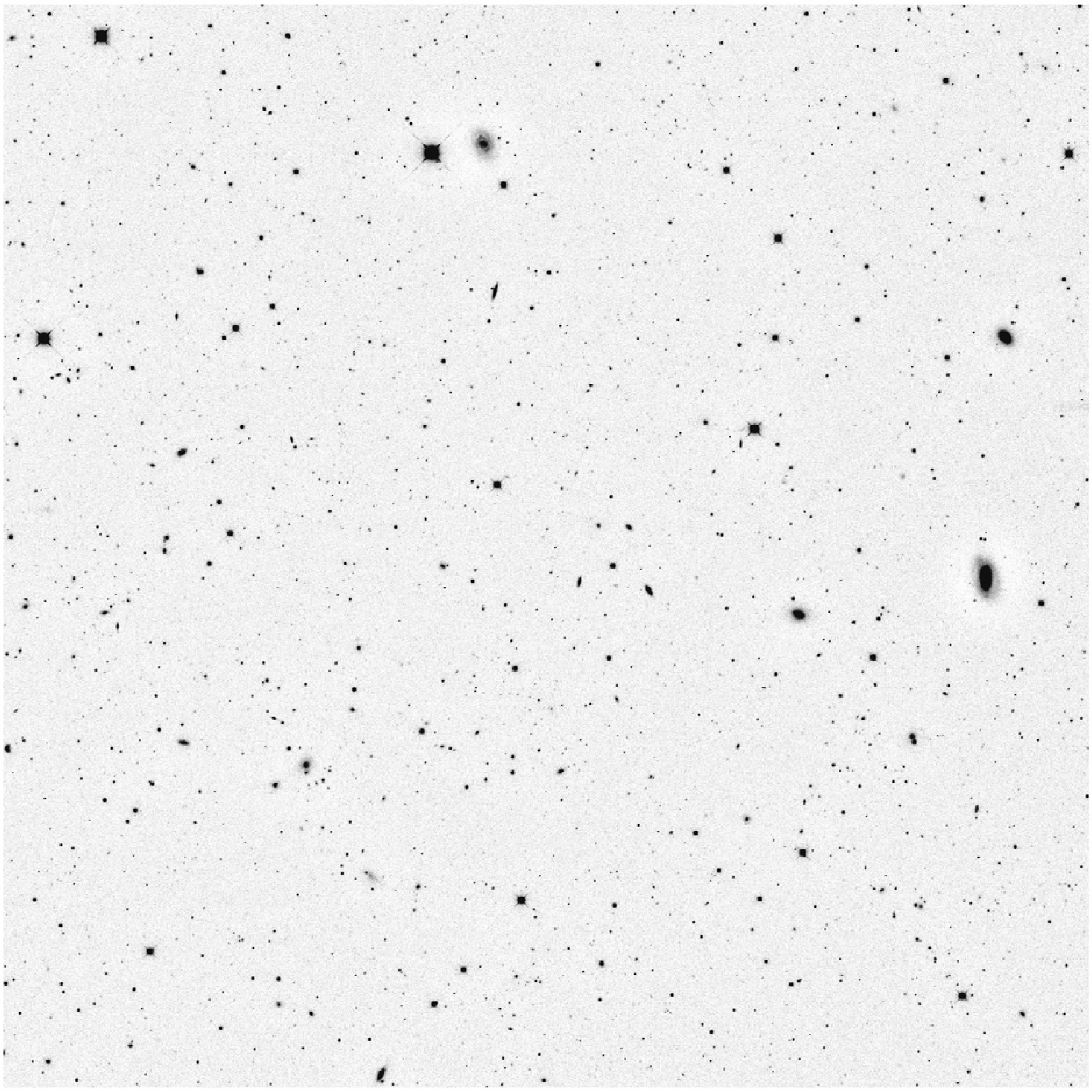


Figure 45 Pipeline result for a sparsely populated field.

This is the sum of 25 exposures in H. The single exposure was 3sec, 20 exposures were coadded in memory. Thus the total integration time is 25 min. The 5σ limiting magnitude as determined from 2MASS stars and the background noise is 20.8^{mag} (2" aperture, seeing 0.9").

Note the over-corrected background around objects extended more than the dither amplitude. This is due to the sky being determined from images of the same field.

14.3.2. Images taken with o2k/sky_point

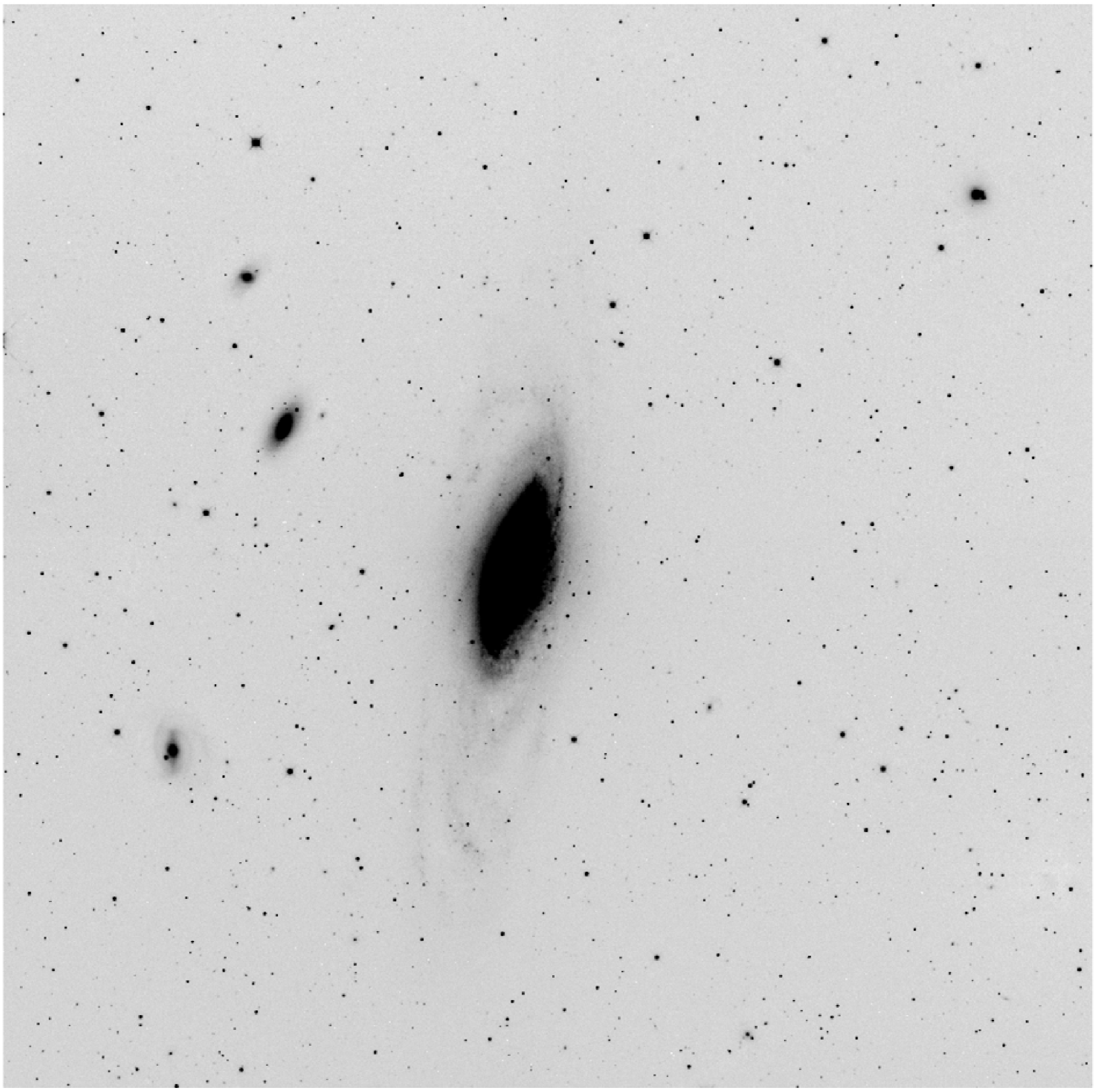


Figure 46 Pipeline result for an image of an extended object.

NGC7331 in the H-band. For this image 8 exposures of 30sec exposure time (5sec and 6 co-adds in memory) were used. The sky was taken 20' north of the galaxy.

For extended objects the sky mode should be set to `minimum`. This ensures that the background is taken mainly from the sky exposures and will not be influenced too much by the extended object. The angular distance of each exposure relative to the first one in the catalogue is limited to typical dither offsets. So the sky exposures are ignored in the summed image.

Appendix 1 Filters[5]

Broad band filters

Filter	cut on 5%	cut on 50%	cut off 50%	cut off 5%	comment	block
z	0.81	0.83	0.98	0.99	SDSS / ISSAC	*
Y	0.97	0.996	1.069	1.099	MANOS	*
J	1.09	1.10	1.345	1.355		
J_{low}	1.146	1.156	1.250	1.259	MANOS	
J_{high}	1.243	1.254	1.359	1.369	MANOS	
Js	1.15	1.165	1.325	1.335	NIRI J	
H	1.485	1.51	1.785	1.810	2MASS	*
K'	1.86	1.94	2.28	2.34		
Ks	1.97	2.00	2.30	2.33	2MASS	
K	1.97	2.00	2.40	2.42		
Methane off	1.52	1.53	1.62	1.63	T dwarfs	*
Methane on	1.63	1.64	1.75	1.76	T dwarfs	*

Table 3: Broad band filters

Narrow band filters (1%)

Filter	central wave	comments	block
He I	1.083		
Pa γ	1.094		
J_{small}	1.187	not available	
continuum	1.207		*
O I	1.237		
Fe II	1.257		
Pa β	1.282		
Fe II	1.644		
continuum	1.710		
He I	2.058		
H_2	2.122		
continuum	2.144		*
Br γ	2.166		
H_2	2.248		
continuum	2.260		
CO	2.295	supergiants	*

Important:

Due to the extended detector sensitivity beyond 2.6μ, several filters need to be blocked in the long wavelength part by an additional blocking filter. These are marked by an asterisk in the last column. Filter selection should always be done via the wheel macro, which automatically inserts the appropriate blocking filter and corrects also the focus shift.

Using a blocking filter changes the image scale by ~2.5/1000 !

Table 4: Narrow band filters

[5] All wavelength specifications are in micron.

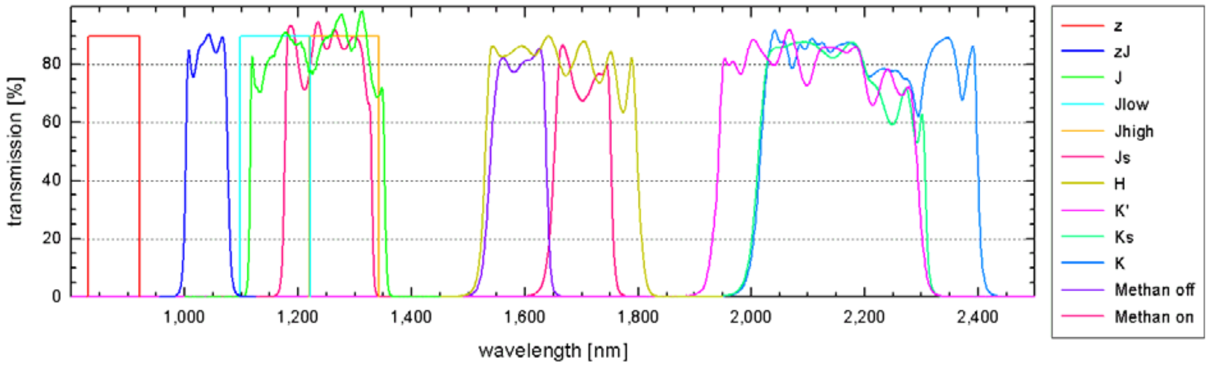


Figure 47: Transmission curves for brad band filters

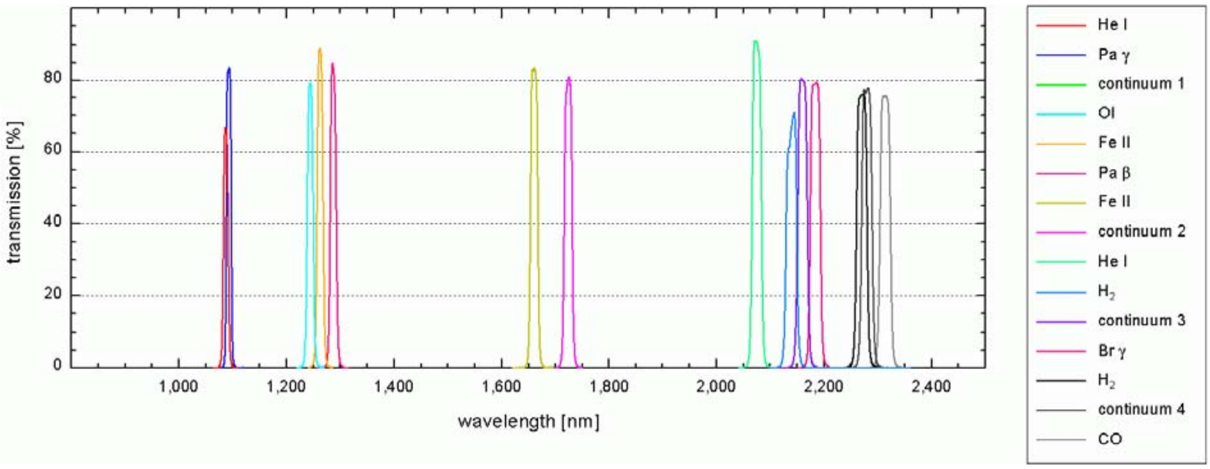


Figure 48: Transmission curves for narrow band filters

Appendix 2 Flat field exposure times

Dome flats The exposure times are for a count level of 15.000 cts/pixel.

Filter	***λ_{centre} [µ]***	***lamp***	***Mirror cover***	***Δt [sec]***	***remark***
z					
Y					
J					
J_{lower}					
J_{uper}					
Js					
H					
K'					
Ks					
K					
Methane off					
Methane on					
He I	1.083				
Pa γ	1.094				
J_{small}	1.187				
continuum	1.207				
O I	1.237				
Fe II	1.257				
Pa β	1.282				
Fe II	1.644				
continuum	1.710				
He I	2.058				
H_2	2.122				
continuum	2.144				
Br γ	2.166				
H_2	2.248				
continuum	2.260				
CO	2.295				

Table 5: Exposure times for dome flats

Twilight flats

It is assumed that the telescope is pointing a direction away from the sun and that the sky is clear (no clouds).

Filter	*λ_{centre} [µ]*	*elevation of sun*	*telescope elevation*	*Δt [sec]*	*remark*
z					
Y					
J					
J_{lower}					
J_{uper}					
Js					
H					
K'					
Ks					
K					
Methane off					
Methane on					
He I	1.083				
Pa γ	1.094				
J_{small}	1.187				
continuum	1.207				
O I	1.237				
Fe II	1.257				
Pa β	1.282				
Fe II	1.644				
continuum	1.710				
He I	2.058				
H_2	2.122				
continuum	2.144				
Br γ	2.166				
H_2	2.248				
continuum	2.260				
CO	2.295				

Table 6: Exposure times for twilight flats

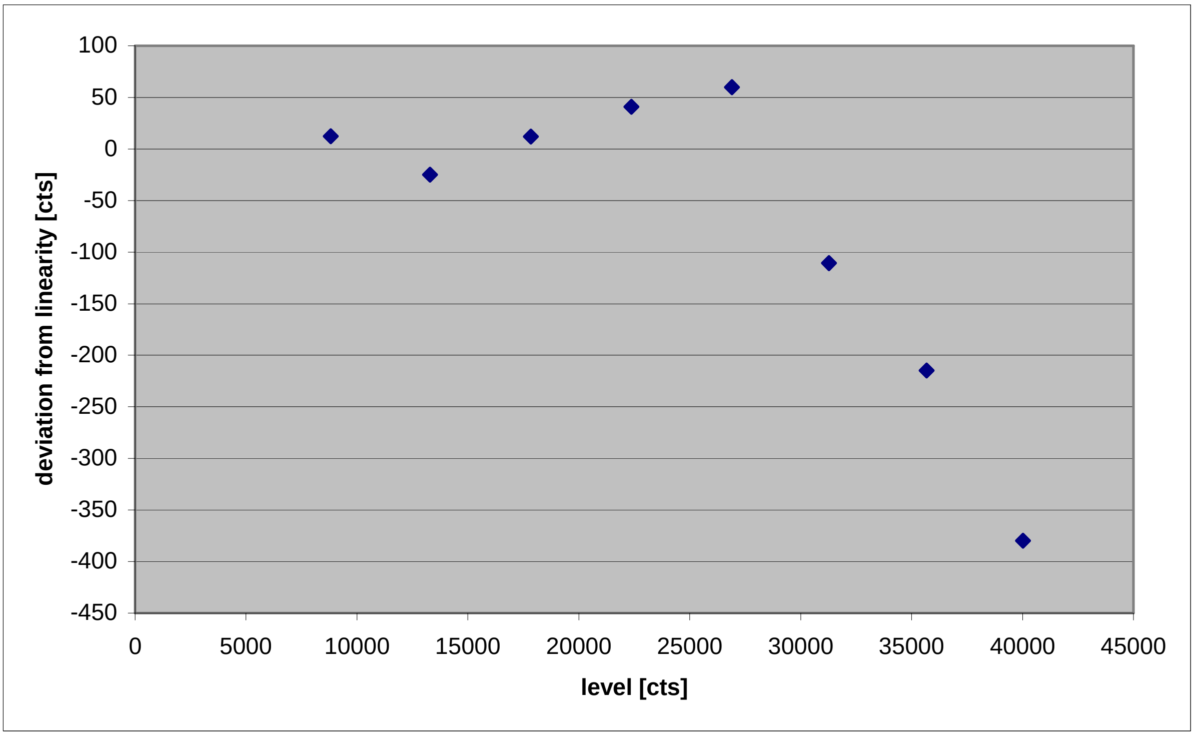
Appendix 3 Detector properties

Read-out modi

- o2dcr = double correlated read
- fcr = double correlated read with fast reset
- lir = line interlaced mode (recommended mode)

Make sure the idle mode is set to `wait`. Check with `idle` in the camera window (red background).

In this mode, the detector is linear to better than 1% up to 25.000 cts. The observing utilities assume a linearity up to 20000cts, to be on the safe side.



The detector should be operated in 32-channel mode (default, to be selected during start-up). Please note that the read-out electronics has to be reset with power off/on after the mode is changed from 32- to 4 channels and vice versa.

Detector saturation

The detector is sensitive towards over exposure and shows an increased "dark current" following over-exposure. Should this accidentally happen (*e.g.* during taking twilight flats) the detector should be read out several times with the blank inserted. This is best done in endless mode and the count level being monitored on the online display.

Gain (g) and readout-noise (RON) per channel for FPA 77 (Kovacs 2006 PhD thesis)

	Fitted (1/g)	***g*** [e^-/ADU]	**Fitted $(\sigma_r/g)^2$**	σ_r^2 [ADU]	**RON** [ADU]
Quadrant 1					
Chan.1	0.2059	4.86	2.1565	50.80	7.1
Chan.2	0.2102	4.76	1.4323	32.48	5.7
Chan.3	0.2166	4.62	3.2364	69.01	8.3
Chan.4	0.2084	4.80	0.2134	4.92	2.2
Chan.5	0.2041	4.90	-2.2312		
Chan.6	0.2066	4.84	3.8764	90.83	9.5
Chan.7	0.2200	4.54	2.3432	48.40	7.0
Chan.8	0.2082	4.80	5.6544	130.41	11.4
Quadrant 2					
Chan.9	0.1883	5.31	1.3214	37.26	6.1
Chan.10	0.1872	5.34	-2.4325		
Chan.11	0.1957	5.11	3.2784	85.59	9.3
Chan.12	0.1921	5.21	2.4324	65.93	8.1
Chan.13	0.1983	5.04	6.3476	161.45	12.7
Chan.14	0.1946	5.14	1.7654	46.63	6.8
Chan.15	0.1887	5.30	8.5436	239.82	15.5
Chan.16	0.1971	5.07	-1.3221		
Quadrant 3					
Chan.17	0.1942	5.15	4.5435	120.45	11.0
Chan.18	0.1956	5.11	3.4656	90.54	9.5
Chan.19	0.2059	4.86	-1.4324		
Chan.20	0.2105	4.75	2.4343	54.92	7.4
Chan.21	0.1966	5.09	0.8776	22.71	4.8
Chan.22	0.2043	4.90	2.3243	55.70	7.5
Chan.23	0.2028	4.93	1.4355	34.91	5.9
Chan.24	0.2102	4.76	4.3463	98.35	9.9
Quadrant 4					
Chan.25	0.2234	4.48	1.9615	39.32	6.3
Chan.26	0.2352	4.25	2.7455	49.63	7.0
Chan.27	0.2256	4.43	6.8767	135.07	11.6
Chan.28	0.2101	4.76	-1.2423		
Chan.29	0.2089	4.79	4.3651	100.01	10.0
Chan.30	0.2122	4.71	2.5433	56.50	7.5
Chan.31	0.2132	4.69	3.1213	68.66	8.3
Chan.32	0.2274	4.40	1.6456	31.81	5.6
	<gain>	**4.87**		**<RON>**	**8.2**
	+/-	**0.05**		**+/-**	**0.5**

Appendix 4 DAT spooler

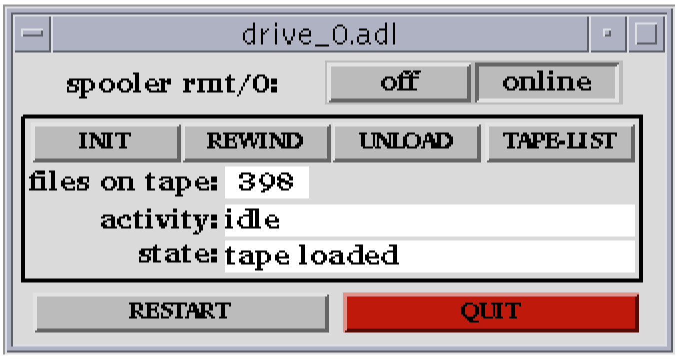


Figure 49: The GUI of the DATspooler. Currently only one drive is supported.

This tool allows automatic saving of data during the night on a DDS4 DAT-tape. A further application of the tool enables to copy data to tape in offline mode. A tape of length 150m will hold approximately 1000 images, depending of course on the save mode.

Launching the spool system including the control GUI

> **`start_datspooler`**
>
> first analyses the status of the tape drives. If a tape is loaded which already contains data, a warning is issued and has to be approved by the user. Via the GUI the tape can be initialized, deleting ist current content.

Data format on DAT

The FITS-files are written as blocked files with a blocking factor of 10 (i.e. record length 28800). Files are separated by an EOF mark.

Using the spooler from within an instrument programm

Usually the instrumentation software calls the via 'systemcall'.

> Call: **`QueueFiles`** *`path/filename`*

Using the spooler from an xterm

- Create a list of FITS-files to be saved into a file *newdata.sav*.
  - *e.g.* with `ls` *`path/`*`*.fits > newdata.sav` (*`path`* to directory, where FITS-files are stored)
- Launch the spooler with
  `QueueFiles` `newdata.sav`

During the tape copy process further files may be entered into the queue!

Checking the tape content

Using the command **FitsList** one may check the content of a tape. The user has to create a file named KEYS.LIST with the help of which the spooler knows, which fits-keywords to list.

Besides that the program also lists the number of records in each file and ist size in bytes. `$DATSPOOLER/config/KEYS.LIST` is used, if the user does not supply a keyword file.

FitsList *device nfiles firstfile*

device	name of the tape drive, *e.g.* `/dev/rmt/0cn`
nfiles	number of files to list
firstfile	first file on tape, with which to start listing

spooler control

`QueueControl reset`
Deletes all entries in the queue.

`QueueControl list`
Lists all files in the queue.

`QueueControl restart`
Restart the spooler. If there are files in the queues not yet copied to tape, these will be now copied.

`QueueControl stop`
Interrupt copying to tape. Resume with restart.

Environments

`DATSPOOLER_DIR/datspooler.cshrc`
It is necessary to call this file once at the beginning by **source** *datspooler.cshrc*. However, in most instancies this is done by the instrument control software.

Files used by the spooler

`DATSPOOLER_DIR/common/spool/dat.spool`
`DATSPOOLER_DIR/common/spool/dat.tmp`
Holds the name of the files to be saved following the call **`QueueFiles`** *`path/file`*. After that thsi file is copied to *dat.tmp*

Programs

All programs are located in DATSPOOLER_DIR/bin/
Those starting with DAT are called from other routines but may also be used directly.

- **`DATeod`** *`dev`*
  Writes an EOD (end of data) mark to tape. If done at the beginning of the tape, this deletes the tape (reset tape)
- **`DATeof`** **`dev`**
  Writes an EOF (end of file) to tape.
- **`DATeom`** **`dev`**
  Positions the tape after the last file (end of medium)
- **`DATfsf`** **`dev nfiles`**
  Skip forward by nfiles files marks.
- **`DATrew`** **`dev`**
  Rewind the tape

- **DATtst** **dev**
  Read tape status
- **DATunl** **dev**
  Eject the tape

- **FitsList** **dev nfiles firstfile**
- **QueueFiles** **path/file.fits oder newdata.sav**
- **QueueControl**
- **StartTapeSpooler**
- **datSpooler.csh**
- **datSpooler.0**
- **datSpooler.1**
- **datSpoolerKillDisplay.csh**

Appendix 5 FITS keywords written by OMEGA2000

```
SIMPLE  =                    T
BITPIX  =                   32
NAXIS   =                    2
NAXIS1  =                 2048
NAXIS2  =                 2048
COMMENT =
BSCALE  =                  1.0
BZERO   =                  0.0
BUNIT   = 'DU/PIXEL'
CTYPE1  = 'PIXEL'
CRPIX1  =                  1.0
CRVAL1  =                  1.0
CDELT1  =                  1.0
CTYPE2  = 'PIXEL'
CRPIX2  =                  1.0
CRVAL2  =                  1.0
CDELT2  =                  1.0
COMMENT =
COMMENT =
COMMENT =
COMMENT =
MJD-OBS =       54370.12989426 / Modified julian date 'days' of observation
DATE-OBS= '2007-09-27T03:07:02.8637'/ UT-date of observation
DATE    = '2007-09-27T03:07:04.0134'/ UT-date of file creation
UT      =           11222.8637 / '03:07:02.8637' UTC (sec) at EOread
LST     =         11944.900000 / local siderial time:  3:19:04 (EOread)
ORIGIN  = 'Centro Astronomico Hispano Aleman (CAHA)'
OBSERVER= 'Montoya'
TELESCOP= 'CA 3.5m'
FRATIO  = 'F/2.35'
TELLONG =            -2.546250 / degrees
TELLAT  =            37.222361 / degrees
TELALT  =          2168.000000 / meters
COMMENT =
COMMENT =
COMMENT =
COMMENT =
COMMENT =
COMMENT =
INSTRUME= 'Omega2000'
CAMERA  = 'HgCdTe (2048x2048) IR-Camera'
OPTIC   = 'wide field'
PIXSCALE=             0.450000 / arcsec/pixel
ELECGAIN=             4.150000 / electrons/DN
ENOISE  =            32.000000 / electrons/read
ELECTRON= 'MPIA IR-ROelectronics Vers. 2'
W1POS   = 'NO/OUT'
W2POS   = 'BLOCK_HK'
W3POS   = 'OPEN'
W4POS   = 'H'
W5POS   = 'none'
W6POS   = 'none'
FILTER  = 'H'                  / filter macro name of filter combinations
FILTERS = 'BLOCK_HK+H'         / combination of all filters used
STRT-INT=           11159.8025 / '03:05:59.8025' start integration (UT sec)
STOP-INT=           11224.6949 / '03:07:04.6949' stop integration  (UT sec)
RA      =            46.630000 / (deg) R.A.:   3:06:31.2
DEC     =             0.993714 / (deg) Dec.:   0:59:37.4
EQUINOX =          2007.758112 / (years)
AIRMASS =             1.241180 / airmass
```

```
HA      =             3.127500 / (deg) H.A. '  0:12:30.6'
T-FOCUS =            24.995600 / telescope focus [mm]
CASSPOS =             0.000000 / cassegrain position rel. to NSEW
POLPOS  =             0.000000 / polarizer position
NODPOS  = 'A-B (main)'
OBJECT  = 'HIROCS 03h 06b (H):1/25'
POINT_NO=                    1 / pointing counter
DITH_NO =                    1 / dither step
EXPO_NO =                    1 / exposure/read counter
FILENAME= '26sep0104.fits'
TPLNAME = 'm31.mac'            / macro/template name
TIMER0  =                  979 / milliseconds
TIMER1  =                 3012 / milliseconds
TIMER2  =              2033100 / microseconds
PTIME   =                    2 / pixel-time (units)
READMODE= 'line.interlaced.read'/ read cycle-type
IDLEMODE= 'wait'               / idle to read transition
SAVEMODE= 'line.interlaced.read'/ save cycle-type
CPAR1   =                    1 / cycle type parameter
ITIME   =             3.012000 / (on chip) integration time [secs]
HCOADDS =                    1 / # of hardware coadds
PCOADDS =                    1 / # of coadded plateaus/periods
SCOADDS =                   20 / # of software coadds
NCOADDS =                   20 / effective coadds (total)
EXPTIME =            60.240002 / total integ. time [secs]
FRAMENUM=                    1 / INTEGRAL OF 20
SKYFRAME= '26sep0103'
SAVEAREA= '[1:2048,1:2048]'
CHOPP-F =             0.000000 / chopper frequency (Hz)
CHOPP-T =             0.000000 / chopper throw (p-p arcsec)
CHOPP-M = 'DC'                 / chopper mode
CHOPP-A =             0.000000 / chopper angle (degrees)
CHOPP-P = 'DC: A'              / chopper position in DC-mode
TEMP-A  =             0.000000 / sensor A [K]
TEMP-B  =             0.000000 / sensor B [K]
PRESS1  =            6.480e-08 / [mbar] '2007-09-27 03:05' 'pressure1'
PRESS2  =            0.000e+00 / [mbar] '2007-09-27 03:05' 'not used'
TEMPMON1=            81.306999 / [K] '2007-09-27 03:05' 'filter box'
TEMPMON2=            81.156998 / [K] '2007-09-27 03:05' 'motor'
TEMPMON3=           475.000000 / [K] '2007-09-27 03:05' 'optics'
TEMPMON4=            75.705002 / [K] '2007-09-27 03:05' 'fanout'
TEMPMON5=            75.622002 / [K] '2007-09-27 03:05' 'detector plate'
TEMPMON6=            75.688004 / [K] '2007-09-27 03:05' 'cold plate'
TEMPMON7=            36.619999 / [K] '2007-09-27 03:05' 'inner shield'
TEMPMON8=            77.925003 / [K] '2007-09-27 03:05' 'outer shield'
ROTSTAT = 'offline'            / rotator table (rottab)
ROT-TK  =                    0 / rottab: tk
ROT-TRM =                    0 / rottab: trmode
ROT-RK  =                    0 / rottab: rk
ROT-RTA =             0.000000 / rottab: rtangle
ROT-RVA =             0.000000 / rottab: rvangle
ROT-CLM =                    0 / rottab: clmode
SOFTWARE= 'GEIRS Vers. 377.sgeneric-xO4 (Jun 14 2005, 12:58:51)'
COMMENT = 'your comment’
END
```

Appendix 6 Complete list of macros

The following macro commands are available in GEIRS
(some are not applicable to OMEGA2000):

```
abort   alarm   aperture   area   autosave   backup   batching   buffers
cassoff   casspos   cd   chopper   clobber   coadds   continue   controls
counter   cplats   crep   ctime   ctype   delay   dir   display   engstatus
engwindow   exit   filter   fits   get   gui   help   history   hpmove
idlemode   init   iniwindow   interactive   instrangle   itime   itype
kill   lamp   last   load   logfile   ls   ls   lyot   macro   median
msio   next   object   observer   optics   pause   pipe   pkginp   polpos
ptime   put   pwd   quit   read   repeat   resets   rmode   rottab   rtime
saad   satcheck   save   set   shminfo   sky   sleep   sndwin   sound
status   stripchart   subwin   sync   system   t0   t1   t2   tdebug   te-
lescope   telgui   tempcontrol   temphistory   tempplot   test   trigger
userstatus   verbose   version   wheel   xserver
```

---

abort

```
type:   USER
syntax: abort [-r  [-k [#]]]  [-d] [-m] [-s] [-t] [-a] [-b]

        Aborts 'read' and 'macro'-execution.
        -r: abort 'read' only
        -d: abort 'save' of data only
        -m: abort 'macro' only
        -s: abort 'sync' only
        -t: abort 'test' only
        -a: abort all processes above here
        -b: abort 'backup'

      -k [#]:  special option to kill read after # waiting seconds
(dflt=2).
      (First tries smooth kill via catchable signal, then urge the kill).

      Default (no switches): abort everything except 'save' and 'backup'.

      On 'read' abort the file geirsLstAbort is written to $CAMTMP (~/tmp)
      and contains date and time of abort.
```

---

alarm

```
type:   USER
syntax: alarm [sound] [volume]

        Play 'General Error' sound. You may enter a 'sound' (file) ,
        but this file must be located in $CAMHOME/SOUNDS.
        'volume' range is from 1 to 100.
```

---

aperture

```
type:   USER
syntax: aperture [name]

        Move the aperture wheel to position 'name'. The named
        positions are defined in the file $CAMINFO/wheel#.ext
        If called without a parameter 'aperture' prints all
        possible aperture-positions and the actual one.
        The wheel'#' and '.ext' depends on the actual camera system.

        'aperture' is a "background" process and should have a 'sync'
```

```
        after it when used in a macro.
```

---

area

```
type:   USER
syntax: area [x1 y1 x2 y2]

        Sets the area of the image that is used for all 'save' operations
        except '-d' (dump file).
        x1/y1: lower left corner
        x2/y2: upper right corner
        'area' without parameters returns the actual save-area.
```

---

autosave

```
type:   USER
syntax: autosave {yes,on/no,off} [-s] [-f n] [-l n] [-r n1 n2] [-1] [-i] [-
d]

        Enables/disables automatic 'save'-operation after/during a 'read'.
        The switches are explained with the save-command.
        Without parameter the actual 'autosave-status' is printed.
```

---

backup

```
type:   USER
syntax: backup path [device]

        Copies all files in the directory 'path' to 'device'.
        You must enter the full path (beginning with '/').
        You have to set the actual save-path to a different
        directory than the one to be copied.

        Default device is /dev/rmt/0n for max@moritz and /dev/rmt/1n
        for omega@omega and magic@omega.

        example: backup /disk-a/user /dev/rmt/1n

        -------------------------------------------------------------

        WARNING !!! Use only if you know what you are doing !!!

        This routine uses 'dd' to copy files from disk to tape.
        Nothing else!

        If you are not sure what this means to your data use 'tar' as
        backup program. e.g.:
        > cd /disk-a/max
        > tar cvf /dev/rmt/0 29nov96

        --------------------------------------------------------------

syntax: backup -abort

        Aborts a running backup.
```

---

batching

```
type:   USER
syntax: batching [n]

      Switches the batching size for GEIRS package streams
      to number n=1,... .
      Without argument the current status is shown.
```

---

buffers

```
type:   USER
```

```
syntax: buffer {auto,manual}

        Switch auto-update / manual-update of buffers. If in auto-mode
        after every read all data is automatically added to the
        appropriate buffer (main/offset position of UKIRT).

syntax: buffer update

        This command adds the images of the last read to the main/offset
        telescope position buffers. If the data is already up-to-date
        the software will send an error message.

syntax: buffer clear

        Clear main/offset buffers.

        All 'buffer' commands are availale with Max/UKIRT only!
```

---

cassoff

```
type:   USER
syntax: cassoff [angle]

        Sets 'angle' as the cassegrain-angle for the NSEW orientation.
        (zero-point).
```

---

casspos

```
type:   USER
syntax: casspos [angle]

        Sets 'angle' as the actual cassegrain angle. (Just a FITS-
        header entry)
        Without parameter the actual cassegrain-angle relative to NSEW
        will be printed.
        This is 'actual cass.angle' - 'cassoff'. This value
        is written into the FITS-headers as CASSPOS.
```

---

cd

```
type:   USER
syntax: cd [directory]

        Changes directory for 'save' operations (UNIX style).

        If you change the directory the new filesystem will be
        checked. If the capacity is below a certain value you
        will receive a warning from the system.

      To check the currently usde directory use the command
      'cd .' to get the directory and the free capacity.

      If a basename was given for the default-filename, the
      new directory is searched for matching filenames, which
      could result in a conflict (by a larger digit value in the name).
      If a possible conflict was found next free larger value
      is taken as next default-filename, else the default-filename
      stays the same.

      Without argument the directory is UNIX-like set to the home
      directory of the user.
      The directory 'save-path' and the freespace is always output.
```

---

chopper

```
type:   USER
```

```
        !!! this command is available at UKIRT only!!!

syntax: chopper beam [{A,B}]

        Set chopper to position A or B (swithes to DC-mode)
        The communication is done through IRL-electronics.

syntax: chopper throw [arcsec]

        Defines chopper throw (peak-peak) in arcsec on the sky.
        This command just changes the FITS-header (no communication
        to the telescope).

syntax: chopper angle [degrees]

        Defines the chopping angle.
        This command just changes the FITS-header (no communication
        to the telescope).

syntax: chopper mode [{rectangle,sawtooth,dc}]

        Defines the chopper mode.
        This command just changes the FITS-header (no communication
        to the telescope).
```

---

clobber

```
type:   USER
syntax: clobber {yes,no,on,off}

        Enables/disables overwriting existing files. Default is 'no'.
```

---

coadds

```
type:   USER
syntax: coadds [[-t] or [#subreps [#skips]]]

        Sets # of coadds.
      For Midi: (# of coadds + # of skips) is identical with
                # of subrep (sub-repeats) done by ROE.
              At saving time #coadds are coadded to a
              single 'crep' image.

      Option   #skips  defines the first '#skips' of #subreps
                 to be thrown away.

      Option  -t is used without other arguments, and just checks
                the last 'coadd' and 'itime' command, if the
              values has to be adjusted according to possible
              combinations of coadds and minimal sub-integration.
              If there are adjustment found, a warning is given.

      Without option the current state is shown:
           coadds: 1 sub-skip 6 wanted-coadds: 9
        which informs that the last subrep count set was '9' but the
        last efficient integration time to use were to small and only
      single coadd-read instead of 3 reads fits additional to the
        6 skipped into that efficient integration time.

        Attention: For Midi the itime (as effective itime of a coadded
      image is hold constant, when 'coadds'-command or 'itype'-
      command is used).
      This will perhaps first adjust the coadd-value automatically
      to smaller values, or/and than adjust the subitime-value
      to larger values.
```

```
        (available for Midi as SW coadding with skipping option:
         the # of the values are currently restricted to the looping
         counter inside of ROE2 by maximal value 8191).
        (available for Max128/Max256 as HW coadding w/o skipping option)
```

---

continue

```
type:   USER
syntax: continue

        Continues paused macro and commands.
```

---

controls

```
type:   USER
syntax: control [-x xserver] [-f font]

        opens the main camera-control GUI window.
        -x: where to open the window (e.g. xt28:0)
        -f: font-family (e.g. lucida)
```

---

counter

```
type:   USER
syntax: counter [name [action [set-value/incr-count]]]

        changes the counter 'name' according to action
          clear: or 'clr': sets the counter 'name' to 0
          incr : increments counter (default 1)
        decr : decrements counter (default 1)
        set  : sets counter to set-value

      examples: (counter EXPO_NO is automatically incremented
                 after each 'read' execution)
      'counter'    lists the current counters and its values.
      'counter EXPO_NO'  shows the counter EXPO_NO value
      'counter EXPO_NO clear'   sets the counter EXPO_NO to 0
      'counter EXPO_NO incr'    increments counter EXPO_NO
      'counter EXPO_NO decr 2'  decrements counter EXPO_NO by 2
      'counter EXPO_NO set 99'  sets the counter EXPO_NO to value 99
           (next read will increment that value;
              saving of current image without read takes the old(!) value,
              to prevent interfering with current ongoing save)
```

---

cplats

```
type:   USER
syntax: cplats [#]

        Set number of co-added plateaus in cycle-types 'chop' and 'chop-d'.
        Max ONLY !
```

---

crep

```
type:   USER
syntax: crep n [[#subrep] [#subrepskip]]

        Sets the cycle repeat count. This defines the number of images
        that will be read after a 'read' command.

      The options #subrep #subrepskip are available for Midi for
         faster setup. Instead using options, you may use for Midi
         the 'coadds' command. Both are complementary and only
         one of the possibility is needed for correct setup.
        If options not given, there values will not be changed.
```

---

ctime
type: USER
syntax: ctime [time-val]

Currently just returns the cycle-time status.

---

ctype
type: USER
syntax: ctype name [parameters]

```
        Sets the cycle-type.
        Number availabele depends on the actual camera:


        Valid cycle-types for Omega2000 are:
        'scr'       single.correlated.read (like 'rr' (first full frame
rst))
        'dcr'       double.correlated.read (like 'rrr' (first full frame
rst))
        'fcr'       double.correlated.read (like 'rrr-mpia' (fast-line-
rst))
        'lir'       line.interlaced.read - a double.correlated read,
                                  (like ''rrr-fmpia')
        'mer'       multiple-endpoint sampling read (like 'mep')
                    also called 'Fowler sampling';
                    parameter: number_of_reads_per_edge
        'srr'       sample-up-the-ramp read (see also 'ramp')
                    parameter: # of reads on the ramp
        'sub-xxx'   subarray mode in corresponding xxx type;
                    parameters: center-x center-y size
        (engineering modes of Omega2000):
        'spr'       single-pixel-read, stays on the pixel and clocks
                    as often as the field size of the channel;
                    parameters: x-pos y-pos
        'rlr'       reset-level-read, holds the reset-level and reads the
                    array
```

---

delay
type: ENG
syntax: delay [#]

Set 'delay' between two cycles. Unit = milliseconds.
MPIA electronics only!

---

dir
type: USER
syntax: dir [filenames]

Executes 'ls -l' in current directory. The output stops after 1 page,
to proceed with the next page, enter: <RETURN>
to abort the output, enter: q<RETURN>

---

display
type: USER
syntax: display [-c #] [-l table] [-i #] [-x xserver] [-f font] [-p]

-c: # of colors {4..240} (default=100)
-l: color-lookup-table {gray,temp,heat} (default=gray)
-i: image size {256,512,1024}

```
    (default=256 for Magic+Max, 512 for Omega)
-x: where to open the window (e.g. xt28:0)
-f: font-family (e.g. lucida)
-p: without argument: only tries to get private colormap
```

---

engstatus

```
type:   ENG
syntax: engstatus

        Requests the engineering status from the camera and
        prints it on the screen.

        After a 'Re-Send Params' in the Control-Window, the
        returned values of 'engstatus' should be like this:

       Omega(MPIA):
          ctype=2
          time=0 x 10ms
          crep=1
          delay=
          rt=
          rpc=
          e_omega 23.01.1997 17:01

        Max/Omega(IRL): not available
```

---

engwindow

```
type:   ENG
syntax: engwin

        Opens engineering-info window.
```

---

exit

```
type:   ENG
syntax: exit

        Shut-down of the camera-software. Within a macro it will
        just terminate macro-execution.
        see 'quit'
```

---

filter

```
type:   USER
syntax: filter [position]

        Where 'position' is a filter-macro defined in $HOME/info/fmacros.x

        These macros define the position of all wheels following:
        '*' means: use the default position (availabel for lyot-stop only)
        '-' means: leave this wheel as it is.

        Without parameter 'filter' shows all available filter macros
        and the actual one.

        'filter' is a "background" process and should have a 'sync'
        after it when used in a macro.
```

---

fits

```
type:   USER
syntax: fits

        Prints the actual FITS-header. The output stops after 1 page,
        to proceed with the next page, enter: <RETURN>
        to abort the output, enter: q<RETURN>
```

```
syntax: fits comment text

        Sets 'text' in the FITS-header as COMMENT.
```

---

get

```
type:   ENG
syntax: get offset [{-i,-f,-d,-s}]

        Prints shared-menor page entry 'offset'.
        -i: integer entry (default)
        -f: float entry
        -d: double entry
        -s: string entry
```

---

gui

```
type:   USER
syntax: gui [-x xserver] [-f font]

        starts a graphical user interface (GUI) for the camera.
        For the description of the otions see 'help control'
```

---

help

```
type:   USER
syntax: help

        prints the list of commands.

syntax: help command

        prints information about the specified 'command'
        'syntax' descirebes the (various) parameters and switches.
        'type'   USER:  normal user command
                 ENG:   engineering command, not needed for standard
                        operations
                 SUPER: system safety critical commands. A password is
                        required to use such a command.
                        (the observer's name has to be the password)
        Parameters in '[]' are optional. List of exclusive values are
        enclosed in '{}'.

syntax: help -x

        starts a HTML-browser and loads the camera/software
        documentation.
```

---

history

```
type:   USER
syntax: history

        Prints the command history.

syntax: !!

        Repeats the last command.

syntax: !abc

        Repeats the last command that starts with 'abc'.
```

---

hpmove

```
type:   ENG
syntax: hpmove x y
```

```
        Move HP-plotter.
```

---

idlemode

```
type:   USER
syntax: idlemode [action] [threshold]

      Selects the used idlemode (default normally 'auto' with '2secs').
      Without parameters it shows the idlemode status.

      Option 'action' =  'break' interrupts idle clocking to
                                 start the next read immediately
                          'wait'  goes seamless from idle clocking
                                 to clocking of read-out
                         'auto'  uses a integ. time threshold to
                                 decide for one of the above actions.

      Option 'threshold' = float value of integration time. Below
           that value, idlemode 'wait' is used else idlemode 'break'
```

---

init

```
type:   USER
syntax: init camera name [-o optics] [-s status] [-m status] [-t status]

        Initialize the camera. Valid camera-names and optics are defined
        in $CAMHOME/src/camera.h

      If no 'name' is given, the current settings are used and checked.

    camera: = {BlueMagic,BlackMagic,Max128,Max256,OmegaPrime_IRL,
               OmegaPrime_MPIA,OmegaCass_IRL,OmegaCass_MPIA}
        -o: optics = {wide,high,very,side,down}
        -s: status = {offline,online}
        -m: motors = {offline,camera,direct}
        -t: temperature-controller = {offline,camera,direct}

syntax: init telescope name [-f number] [-s status]

        Initialize the telescope. Valid telescope-names and focal-ratios
        are defined in $CAMHOME/src/camera.h

 telescope: = {lab,ca35,ca22,ca12,hd07,ukirt}
        -f: focal-ratio = {3,8,10,25,35,45}
        -s: status = {offline,EPICS,serial}

syntax: init wheels

        Read filter/aperture - wheel database and move wheels
        to the ZERO-position (detent-position).
```

---

iniwindow

```
type:   USER
syntax: iniwin

        Opens a window to setup the camera/telescope configuration.
        If you leave the window using the 'OK'-button, the camera,
        the telescope and the wheels will be initialized if their
        setup was changed.
        'all' forces a complete re-initialization whether or not
        anything was changed.
```

---

interactive

```
type:   ENG
syntax: interactive [{on,off,yes,no}]

        If you use the interactive-mode, the outputs are blocked
        after 19 lines, until you enter <RETURN>. Default is 'yes'.
        (All shell outputs are blocking if you use interactive=yes,
         and you may lose messages if you set interactive=no.)
```

---

instrangle

```
type:   USER
syntax: instrangle [angle]

        Sets 'angle' as the instrument-angle for the NSEW orientation.
        For relativ telescope movements the complete correction angle
        is currently:
        'given fratio (e.g. ALFA-F25 == -22.0)-angle' + instrangle.

        Without parameter the actual 'field of view' angle relative to NSEW
        will be printed (counter clockwise).
        The complete cassegrain angle would be
        casspos(=actual cass.angle-'cassoff')+instrangle+given-fratio-
angle.
        (This value should be written into the FITS-headers as CASSPOS
(?)).
```

---

itime

```
type:   USER
syntax: itime [time] [-stdout / -stderr] [-o[ffset] #sec] [-m[ultiple]
        #sec]

       Set the integration-time 'time' in seconds. Without 'time' argument
       it prints the actual integration-time status.
       If the one of the options [-stdout] or [-stderr] is given, the
       status value is additionally printed to the according output-stream.

       The options [-o] and [-m] are specifying adjustment and offset val-
       ues, which are valid and used, until the value(s) are set back to
       0.0 according to the formula:
                 used itime = '-m'ultiple-adjustment + '-o'ffset

       ex.:  -o 0.030   adds a constant offset of 0.030 seconds
       ex.:  -m 0.020   adjusts itime to a multiple of 0.020 seconds (50Hz)
                         (multiple adjusted itime always >= given itime)

       Attention: These values can be configured by the staff via the envi-
                  ronment variables CAMITIME_MULT and CAMITIME_PLUS, else
                  the default value is 0.0 or 0.0, but may be always be
                  changed via the itime command by the user.
```

---

itype

```
type:   USER
syntax: itype [type]

        Set the integration-type as IWR or ITR. Without [type]
        it prints the actual integration-type.
```

---

kill

```
type:   USER
syntax: kill name
```

```
        Sends a 'software-terminate flag' to a subprocess if 'name' is from
        {display,satcheck,engwin,sdisp,gui,control,stripchart,telgui,
        tempcon,shminfo,rottab,iniwin}
        However, a 'terminate' does not necessarily mean that the
        process is able to catch the signal since the mechanism works
        passively (sets a flag).

syntax: kill name

        Send first a 'kill' signal to a subprocess if 'name is from
        {read,save,shell,tele,wheel,filter,lyot,aperture,optics}.
        If after timeout of currently 10 seconds the process has not
        been ended, a 'kill -9' signal is send to the subprocess.
        Additionally the PID-entries and serial line flags are cleared.
        (and maybe some other flags, which has to be reset).
```

---

lamp

```
type:   USER
syntax: lamp {on,off,in,out,offs +#, offs -#}

      Controls the calibration lamp slider and the power of the
      calibration lamp.
```

---

last

```
type:   USER
syntax: last [destfile]

      Returns the last filename of the last image saved
        and stores it also into 'destfile', which by default
        is in directory $CAMTMP (mostly ~/tmp) the file 'geirsLstFile'.
```

---

load

```
type:   USER
syntax: load filename [n]

        Loads 'n' FITS-files into the shared memory. Since the
        shared memory frame-buffers are unsigned short integers, ???
        the displayed values may be not correct.
        You also have to switch the cycle-type to reset.read (rr).
        negative n: add to shm
```

---

logfile

```
type:   USER
syntax: logfile [filename]

        If given, sets 'filename' as logfile name. Otherwise prints
        the actual logfile-name.

Format of the logfile:

UT FILENAME # OBJECT RA DEC EQ AM ITIME COADDS WHEEL-1 WHEEL-2 ...

UT:         universal time
FILENAME:   first filename of this entry
#:          number of files in this entry
OBJECT:     object name
RA:         right ascension (if DACS/TECS connected, else 0.0)
DEC:        declination (if DACS/TECS connected, else 0.0)
EQ:         equinox
AM:         airmass (if DACS/TECS connected, else 1.0)
ITIME       on-chip integration time
COADDS      number of coadded integrations per file
WHEEL-#     position name of wheel-#
```

ls
```
type:   USER
syntax: ls [switches] [filename]

        Executes 'ls' (UNIX style)
```

ls
```
type:   USER
syntax: ls

        Print contents of current 'save'-directory. (see 'dir')
```

lyot
```
type:   USER
syntax: lyot [name]

        Move the lyot-stop wheel to position 'name'. The named
        positions are defined in the file $HOME/info/wheel2.

        Without parameter this command prints all possible
        lyot-position names and the actual one.

        'lyot' is a "background" process and should have a 'sync'
        after it when used in a macro.
```

macro
```
type:   USER
syntax: macro [-c[lear] [filename]

        Executes the macro 'filename'

      If [-c[clear]] option is given alone the last macroname
        is just cleared.

        This macro-file contains commands like you use with
        the shell. Be careful when invoking commands like
        'read', 'telescope' or 'filter' that run in the
        background. Make sure that the next command does
        not conflict with the previous or use the 'sync'
        command.
        The default-directory for the macros is $HOME. If
        you want to start the macro test.mac in $HOME/macros
        then enter 'macro macros/test.mac'.

        It is posible to write comments into your macros using
        a ';' (semi-colon). The lines are truncated at the point
        where the first ';' was found, before the line is executed.
        If the first character in a line is a ';', this line will
        not be executed.
```

median
```
type:   ENG
syntax: median [-r[aw]] [[-stdout] or [-stderr]]  [n1 n2]  [x1 y1 x2 y2]

        Calculates the median of images 'n1' through 'n2'.
        Default is all images.
        The options starting with '-' have to be the first parameters
        before the images nX or the areas xX.
        Optional you might using the subarray [x1,y1 - x2,y2] parameter
        only. (Attention: using the wrong area in subarray-images,
        the behaviour  is unspecified).
```

```
    It appends the result to the file '$CAMTMP/median.log',
    where additionally the integration time [sec] is written in front
    of the median

  Options
   -stdout/-stderr :  delivers to the according data stream
                      only the resulting value numbers
   -r[aw]          :  does not take the single image resulting
                      normally from the read-out mode, but
                      all single frames of the image for the
                      calculation.

  Example: 'median' of 2 images in the buffer
        median(1): 2004
        median(2): 2003
        ave(medians): 2003.50

  Example: 'median -raw' of 2 double-corr. images in the buffer
        median(1): 1004 2007
        median(2): 1003   2001
        ave(medians): 1003.50 2004.00

  where with the -stdout or -stderr only the resulting
          2003.50
  or
        1003.50,2004.00
  is delivered to the according datastream.
```

---

msio

```
type:   ENG
syntax: msio drive command

        Sends 'command' to motor-drive 'drive'. (prvileged command)

        This command is used for test with the wheels.
        'command' uses the syntax of the motor drives: e.g.:

        'move 10'       moves the motor +10 steps
        'move -20'      moves the motor -20 steps
        'pos 9000'      moves the motor to the absolute position 9000
        'ver p'         returns the absolute position in motor steps
        drive =  1: lower filter
                 2: lyot stop
                 3: upper filter
                 4: aperture

        OmegaCass:
        commands e.g.:
        'IS'     status of switches and home switch.
        'PR'     absolut position or position since power on.
        'D3000 3G 3CR' moves motor3  3000 steps or to absolute position
3000
                 and waits on end of execution.
        drive =  1: optics
                 2: pol/grism
                 3: lyot
                 4: filter-2
                 5: filter-1
                 6: aperture

        msio always waits for a reponse from motor!
```

---

next

```
type:   USER
syntax: next [-t or -n] [filename]

        Sets 'filename' as the default-filename. This filename
        is used, when no filename is given with the 'save' command.

      Auto-numbering:
        A filename with an alpha-char at the end (basename), will
        automatically be extended  with 4 digits, where first the
        current save-path is looked-up for any files which contain
        any of the GEIRS extensions with the basename and 4 digits
        at the end. Then the next free digits count is added to the
        given basename and used as next filename.

      Option '-t' with or without a filename tells the system, that
        the next 'save' command is not allowed to use the current
        next default-filename, but a special testfile-name.
        After the next 'save'-command the default-filename is
        automatically reactivated, also if there was an error or
        problem with the 'save' command (Multiple save-orders in
        a single 'save' command are treated as a single 'save'-command).

      If option '-t' is given without a filename, the special name
      'test' is used, else it uses the given filename.
      But the testfile-filename is not used, if the next 'save'
      command is given with a filename.

      To deactivate the just triggered next special test-filename,
      you might either just call
           next -n    without filename argument,
        or next -n filename, where filename will be handled like above,
        or next filename, where filename will be handled like above

      Without any argument, the command returns the next default-
      and next test-filename, where the one which would be used
      at the next 'save' command, when 'save' is given without
      a filename-argument, is marked as 'next:'.
      (The 'test-filename' shows you also the starting string of
      the saved files, which are not queued to automatic storing
      to tape, etc).
```

---

object

```
type:   USER
syntax: object text

        Sets 'text' as object in the FITS-header.

syntax: object

        Prints the actual object.
```

---

observer

```
type:   USER
syntax: observer name

        Sets 'name' as observer in the FITS-header.
        This name is used as password for the privileged commands.

syntax: observer ?

        Prints the actual observer's name.
```

```
optics
type:   USER
syntax: optics [wheel-position]

        Moves camera-optics wheel. Without parameter all possible
        positions and the actual position are printed.
        (OmegaCass only)

        'optics' is a "background" process and should have a 'sync'
        after it when used in a macro.
```

```
pause
type:   USER
syntax: pause [macro]

        Stops any command execution (only continue or kill is executed).
        With option 'macro', pause will only get active if a macro is
        found running.
      Commands/macro will be continued by
        entering the 'continue' command or may be aborted by 'abort'.
```

```
pipe
type:   SUPER
syntax: pipe [-nowait] [-list] command [par1] [par2] [...]

        Send 'command' and 'parameters' directly to the camera-electonics.
        No interpreation or limit checking is performed.

        -n[owait] just send command but do not wait for any answer.
        -l[ist] takes 'command' as name for a command list file
                (currently used in MIDI and OMEGA2000)
```

```
pkginp
type:   USER
syntax: pkginp [-h] [-c] [devicename]

      Starts read-in process of GEIRS stream packages.
      Accepts only devicenames starting with '/dev/'.
      If no devicename is given, the devicename has to be set
         via the environment PKGINPORT, else you get an error.
         (should prevent accidential access of data ports just used).
        Option -h  shows the command usage.
        Option -c  first reads all waiting data until a timeout
           of a a part of a second.
```

```
polpos
type:   USER
syntax: polpos value

        Writes 'value' at keyword POLPOS into the FITS-header.
```

```
ptime
type:   ENG
syntax  ptime [#]

        not available with the MAX (10um) camera and with Omega +
        MPIA-electronics.
```

```
put
type:   ENG
syntax: put [{-i,-f,-d,-s}] offset value
```

```
        Write 'value' at 'offset' into the shared-memory-infopage (data-
base).
        -i: 'value' is an (int) (default)
        -f: 'value' is a (float)
        -d: 'value' is a (double)
        -s: 'value' is a (char*)
```

---

pwd

```
type:   USER
syntax: pwd

        Prints actual directory for the 'save' operation. (UNIX style).
```

---

quit

```
type:   USER
syntax: quit

        Leaves the command-shell and kills all subprocesses.
        (display,gui,telgui,satcheck ...)

        If encountered during executing a macro, 'quit' just terminates
        the macro.
```

---

read

```
type:   USER
syntax: read [-c]

        Read 'crep' images according to the actual cycle type.

        -c: continous read of 'crep' images until 'abort'.

        'read' is a "background" process and should have a 'sync'
        after it when used in a macro.
```

---

repeat

```
type:   USER
syntax: repeat # "command arg ..."

      Repeat for the number # the 'command'. (The 'command' is
      always executed as foreground process inside 'repeat')
```

---

resets

```
type:   ENG
syntax: resets [#]

        Set the number of resets (Max only).
```

---

rmode

```
type:   ENG
syntax  rmode [{slow,fast}]

        Set reset mode (Max,Omega + (new) IRL electronics only).
        Note: 'fast' reset-mode is not implemented.
```

---

rottab

```
type:   USER
syntax: rottab [-x display] [-m]

        Starts rotator-table GUI.
        -x: display name
        -m: mute mode (do no talk to device: for tests only)
```

---

rtime

```
type:   ENG
syntax: rtime [#]

        Set reset-time = # of clock-tics at the beginning of each
        cycle-line. (MPIA electronics only)
```

---

saad

```
type:   ENG
syntax: saad x y d

        Do shift&add on images #2 through #n. Find peak pixel around
        (x,y) in a box of size 'd'.
        Overwrite image#1 with the result of the shift&add procedure.
```

---

satcheck

```
type:   USER
syntax: satcheck on [limit]

        Switches the saturation check on. The optional limit uses
        absolute counts of the A/D converter. These counts range
        from about 10000 - 55000. The non-linearity starts at
        about 40000 counts, which is the default limit.
        If 'sound' is on, you get a accoustic warning.

syntax: satcheck off

        Switches the saturation check off. This is recomended at
        intgration times smaller than about 150 ms. (Magic-Cameras)
```

---

save

```
type:   USER
syntax: save  [-s] [[-f n] [-l n] [-r n1 n2] [-i] [-1] [-d] [-c]
               [-t] [[-b] or [-g]] [-p] [filename/devname] , ...]

        Save frames in the shared memory according to the actual
        cycle type (ctype).
      ATTENTION:  All files starting with the '
                  prohibits the automatic storage on tape with the
                    'datspooler'-tool at CalarAlto.

      A comma delimits multiple saving sets, done from the same
        data (might be sequential or parallel executed from software).
        -f: save from frame 'n' (= 'first frame is')
        -l: save upto frame 'n' (= 'last frame is')
        -r: save only frames from 'n1' through 'n2'. Default is all.
        -i: save the integral of the selected frames.
        -1: write all images into one FITS-file (=FITS-cube).
      -t: save all images as FITS bin-table file (Jaffe/Cotton).
        -b: split the data into fitstable batches and write to dest.
        -g: split the data into single DCR-images and write to dest.
        -d: do not create FITS-files. Just dump the shared-memory
            framebuffer.
        -c: overwrite existing files (for this save-operation only).
      -p: save not the actual sequence but the previous one.
      -s: speed-up version of autosave by immediate direct buffer
          saving, while reading the buffer (in contrast to normal
          autosave without the '-s' option, which is saving the data
          after buffer is filled)
          (Currently only supported for MIDI batches and tables).
          If used in a single 'save' command, it takes the
              current read buffer for parallel saving.
```

```
Attention: Option -p is only thought for interactive usage. It is not
  a good idea to use it in a macro !

  If no filename is given, the default filename is used.

With option -b the filename might be a device '/dev/pcd1'.

Example: save -p -1 , -p -i , -1 , -i

    which saves the previous sequence as cube-fits, previous sequence
  as integrated single fits image, actual sequence as cube-fits,
  and actual sequence as integrated images.

  After a save the filesystem will be ??frequently?? checked. If
  the capacity is below a certain value you will get a
  warning from the system.

Examples:

'save -b -s'           immediately batch-stream to PKGOUTPORT-intf.
'save -b -s filename' immediatelay writes the batch-stream to a file
'save -t filename'    wirtes as a single FITS-table file

'save -g -s'           immediately DCR-img-stream to PKGOUTPORT-intf.
'save -g -s filename' immediately DCR-img-stream to a file

Current PKGOUTPORT interfaces: 'middi', 'dif', '/dev/PCDxx'.

  'save' is a "background" process and should have a 'sync'
  after it when used in a macro.
```

---

set

```
type:   USER
syntax: set macropath [pathname]

        Print or set path for macros.

syntax: set objectpath [pathname]

        Print or set path for object-files.
```

---

shminfo

```
type:   ENG
syntax  shminfo [-x xserver] [-n #] [-t #.#(sec)]

        Opens a window to display shared-memory info-page entries.

        -x: where to open the window (e.g. xt28:0)
        -n: # of entries (default=6)
      -t: #.# (seconds) of pausing
```

---

sky

```
type:   USER
syntax: sky filename

        Writes filename at keyword SKYFRAME into the FITS-header.
```

---

sleep

```
type:   ENG
syntax: sleep #

        Suspend execution of shell/macro for '#' seconds. This is
        the same as with 'sync # none'.
```

sndwin
```
type:   USER
syntax: sndwin

        Opens the sound selector-window. You may also set the volume
        and the output-channel.
```

sound
```
type:   USER
syntax: sound [on|off] [-o {speaker|headphone}] [-v {0..100}]

        Enables/disables sound after some operations like 'read',
        'filter', 'aperture', 'lyot', 'telescope', 'macro', or
        as a warning if the saturation check is on.
        Default is 'off'.

        -o: output = {headphone,speaker}
        -v: volume = {1..100}

        Without parameters 'sound' prints the sound status.
```

status
```
type:   USER
syntax  status

        Returns the comlete status list (depending from
         the SW mode SINGLE/MAIN/INTERFACE)
```

stripchart
```
type:   USER
syntax  stripc [-x xserver]

        Opens the strip-chart window.

        -x: where to open the windwp (e.g. xt28:0)
```

subwin
```
type:   USER
syntax: subwin [HW|SW|auto] [#wid xlstart ylstart xsize ysize]
        subwin on|off [HW|SW|auto] [#wid]
      subwin clear [HW|SW|auto]
      subwin [HW|SW|DET]

      (currently only implemented for instruments with MPIA-ROE2).

      Enables/disables, clears, and sets the hardware[HW] and/or
      software[SW] subwindowing.

      Instead of HW/SW there is also the 'auto' option, where the SW
      will assume, that the given windows has to be acquired via
      optimal HW windowing. So the software will automatically convert
      'auto' given windows to SW and HW windows.

      'subwin on auto' will clear all HW-windows and redefine the
      needed HW windows for the instrument via current SW-windows list.

      If the instrument has no HW-windowing available/enabled, always
      fullframe readout with SW-windowing is executed.

      Subwindows are only added, if the list of subwindows is not
      yet full and '#wid' number is not yet used for a subwindow, where
      '#wid' of SW windows are overwriting any '#wid' of HW window
```

```
definition. But for HW windowing only the '#wid' of the HW-window
definition is used.

Currently max. subwindows count is at least 2 times number of
data output channels of the detector (NQ).

But for ROE2 the max. # of HW windows is given by the
roe_variable.xxx list.

xlstart and ylstart values has to be 1,...,size.

Examples:
activation control:
   subwin off   Any windowing is switched off (only full frame)
   subwin on    HW and SW windowing with current subwin
                  information will be used
   subwin on SW     SW windowing will be used
   subwin off HW    HW windowing will not be used
   subwin off HW 1  Dectivate HW window id #hwid=1
   subwin on  SW 2  Activate (an deactive) SW window #swid=2

window structure setting:
     subwin SW 12 1 1 100 100    SW window with  #wid 12 of size
                  100*100 from left lower edge 1,1 is appended
                  to the list of SW windows, according to unique
                  #wid=12 and window definition free space.
     subwin HW 12 1 1 320 10        HW window with #wid=12

window structure clearing:
   subwin clear HW  Clear all HW windowing definitions
     subwin clear SW  Clear all SW windowing definitions
     subwin clear     Clear all windowing definitions

   ATTENTION: Setting of windows coord, does not include
                activation of any windowing !

PS: Some instrument implementation might apply only
      squared HW-subwindows (taken: xsize^2).
    Other instruments might support only a single HW or
      even SW-window until now.
    MIDI for example implements only HW-windowing
      in y-direction.

  Without or with HW or SW or DET as parameters 'subwin'
prints the current settings (of HW or SW or DET).
```

---

sync

```
type:   USER
syntax: sync [[read] [tele] [filter] [save]] [[none] [all] [macro]] [#]

        Waits for termination of the named process.

        #: sync waits at least '#' seconds, before checking on
           any process to sync for, to ensure startup of previous
           command, which might need time on a busy system;
           (if 'none' (also with others) is given, it does not (!)
           sync on processes).

      If no process parameter is given, 'sync' waits for the
      termination of all background processes listed above and
      currently running in the system.
      Without #time specification (might be given as float),
      the sync waits at least 2 seconds
```

```
  This command is needed for writing macros, since commands
  like 'read' do not block the execution of the next command.
  A typical sequence could look like this:

   read                     ; read data
   sync                     ; wait for all running processes
   tele rel 10 10           ; move telescope 10" north, 10" east
   save -f 2 -i             ; save data
   sync tele                ; wait for the telecope stops
   read                     ; next read
   ...

If a parameter of sync is given as 'macro' or 'all' and
the sync is started from inside of a macro, this 'macro' or
'all' string is just removed.
sync waits only as a command outside of a macro on the
termination of the main macro-level.
'sync' without process specifications always waits on all
processes with the exception of the 'macro' process.
'sync all' waits on all processes including the 'macro' process.
'sync none' waits on neither process, only waits for the
given time (or 2 seconds for default).
```

---

system

```
type:   USER
syntax: system [']cmd[']

        Executes any system command, where 'cmd' might be any
        combination of arguments. On problems with special characters
        surround the cmd with the character "'".
      Example
        system 'tvgcmd 0 "\033"'   to send escape to tv-guider.
                system tvgcmd              to get information about tvgcmd.

        Waits for termination of the system call.
```

---

t0

```
type:   ENG
syntax: t0 [#]

        Set timer-0 to # milliseconds. (IRL-electronics only)
```

---

t1

```
type:   ENG
syntax: t1 [#]

        Set timer-0 to # milliseconds. (IRL-electronics only)
```

---

t2

```
type:   ENG
syntax: t2 [#]

        Set timer-0 to # milliseconds. (IRL-electronics with Max/Omega
only)
```

---

tdebug

```
type:   USER
syntax: tdebug [text [anytext [anytext[]]

      Writes an entry into the debug_${user}.log file in the form
      '2004-05-28 11:23:41.3794 ZD ocass (logentry) all " what ? you
typed.'
```

telescope

```
type:   USER
syntax: tele[scope] abs[solute] hr min sec dg min sec [equinox]

        Moves the telescope to the absolute position
        alpha: 'hr' 'min' sec'
        delta: 'dg' 'min 'sec'

        'tele abs' must not be used within a macro.

syntax: tele[scope] rel[ative] [[zero] or [dalpha ddelta]]

        Moves the telescope 'dalpha' 'ddelta' arc-seconds.

        'tele rel zero': sets the relative offset sum to zero
        'tele rel':      shows the relative offset sum.

        'tele' is a "background" process and should have a 'sync'
        after it when used in a macro.

syntax: tele focus [#]

        Move telescope focus # units (micron)

syntax: tele pos[ition]

        Reads the telescope coordinates.

syntax: tele time

        synchronizes telescope and computer time.

syntax: tele get[allpositions]

        Requests 'tele pos' and 'tele focus'.

syntax: tele nod {main,offset}

        Moves the telescope to the desired nodding position (UKIRT only).

syntax: tele

        Print telescope name and TECS status.
```

telgui

```
type:   USER
syntax: telgui [-x xserver] [-f font]

        Starts a graphical user interface (GUI) to the telescope.

        -x: X-terminal or X-server to connect
        -f: font for menus and buttons
```

tempcontrol

```
type:   USER
syntax: tempc(on) [-x xserver] [-f font]

        Starts temperature controller. Useful for 'Max' only.
        -x: where to open the window (e.g. xt28:0)
        -f: font-family (e.g. lucida)
```

```
temphistory
type:   USER
syntax  temph file [-x time1 time2] [-f time1] [-y temp1 temp2] [-d
xserver]

        see 'tempplot'
```

```
tempplot
type:   USER
syntax: tempp file {[-x time1 time2],[-f time]} [-y temp1 temp2] [-d
xserver]
        Plots temperature log-file. (created by 'tempcon').
        X-axis: minutes, Y-axis: degrees (Kelvin).

        -x: time1/time2 = begin/end time of the graph
        -f: time=start time of the graph
        -y: temp1/temp2 = lower/upper temperature limit of the graph
        -d: where to open the window (e.g. xt28:0)

        This window will NOT be killed when the software is shut-down
        using the 'quit' command.
```

```
test
type:   ENG
syntax: test {std,med,var} [-q #] [-r n1 n2]

        executes array/electronics tests and appends the result to the
        file 'chiptest.log' either in $CAMTMP (normally ~/tmp) or in
        current directory):
        std:  (default): prints averages and deviations over all pixels
              in all images of each single channel and the same for the
              whole image (with additional stdv of channels-stdv).
        med:  prints the median of all channels of each single image
        var:  prints the median of all pixel-averages (time-direction)
              and the median of all pixel-variances (time-direction)

        -r n1 n2: use images 'n1' through 'n2' only (e.g. 'test var -r 2
11')

        -q #    : use quadrant/output '#' only (e.g. 'test var -q 1')
                  (this options is only available for {var} option)
```

```
trigger
type:   USER
syntax  trigger [{extern,wait,intern}]

      trigger switches between external HW-triggering and internal
      starting of ROE via SW. This option is currently only
      used in MIDI.

      Options are
      extern:   - starting read waits on data from ROE endless
      wait:     - synonym to extern
      intern:   - read starts also the ROE data directly

      MIDI uses extern as default, where for all other instruments
        without internal trigger, there is only an intern trigger.

        Without argument it just prints current status.
```

```
userstatus
type:   ENG
```

```
syntax  user

        Prints user status. {astronomer,engineering,superuser}
```

---

verbose

```
type:   USER
syntax: verbose {on,off,yes,no}

        If you set 'verbose yes', you will get more output
        to the screen.
        e.g. while executing a macro the system will print
        every command (and the line number), so you always
        know which macro-line is executed.
        Default is 'yes'.
        Without a parameter 'verbose' prints status of the verbose-flag.
```

---

version

```
type:   USER
syntax: version

      Prints version string of the Software.
```

---

wheel

```
type:   USER
syntax: wheel [ # [[position-name] or [r(elative) #offsetsteps]] ]
      wheel  rdb
      wheel  dialog [on,off]
      wheel  focus  [on,off,new]

      Move wheel number '#' to named position or returns information.
      wheel '#' is the logical wheel order from 0..n as shown by
      the answer of the command 'wheel' itself.
        example
            wheel                  returns overview of all wheels.
                          (reads and shows current wheel-positions!)
            wheel 2                returns information about wheel2.
            wheel 2 wollaston45    moves to wollaston45-element.
            wheel 2 rel -25        moves wheel2 25 steps backwards.
            wheel dialog off       switches GUI warnings/errors.

      'wheel' is a "background" process and should have a 'sync' after it
      when used in a macro.

      'wheel rdb' is re-reading the wheel and wheel-macro database files.
      This command is only valid for OmegaCass and Omega2000.

      'wheel focus [on/off/new]' controls the relative focus adjustment
                          for the selected wheel element combination:

      'wheel focus off'    deactivates the focus correction of all filter-
                           wheels for the next wheel/filter commands until
                           it is reactivated.
      'wheel focus on'     (re-)activates for the next wheel command the
                           focus correction of all filters, which are con-
                           figured for CHKFOCUS-correction in the
                           wheelN.instrument configuration files.
      'wheel focus new'    updates the relative focus-correction informa-
                           tion of the current wheel-combination relative
                           focus for all filters which are configured via
                           CHKFOCUS-correction in the wheelN.instrument
                           configuration files (but does NOT change the
                           on/off state!). I.e. it takes the current focus
```

position as being correct for the current filter combination.

Focus correction is always done relative to the last filter-combination which was saved at the last filter-correction action.

Attention:
Focus settings outside the wheel focus-correction automatism does not influence the correct behaviour of the relative focus-corrections, as long as no combination of (wheel/filter-changes AND manual focus-changes) are done during the state 'wheel focus off':

- to switch relative wheel focus-correction on when wheel-changes AND manual-focus-settings were done in state 'off', use the command 'wheel focus new' to discard the saved last relative focus-correction information and to update it with the current focus.

- initialisation of wheels does not change the focus, but activates the focus-correction for the next wheel usage. (for initialisation the focus-correction is still correct, if no change of the focus-logic were made)

---

xserv**er**
type: USER
syntax: xserver [xserver]

Set default X-display (X-server) name for 'stripchart' and for the "slave"-display.

Appendix 7 Recommended focus fields

Finding charts are from red DSS-II plates and are 20' on a side. The dashed square indicates the field of view of OMEGA2000.

Focus at 1h α(J2000) = $0^h\ 55^m\ 12.33^s$ δ(J2000) = 24° 55' 05"

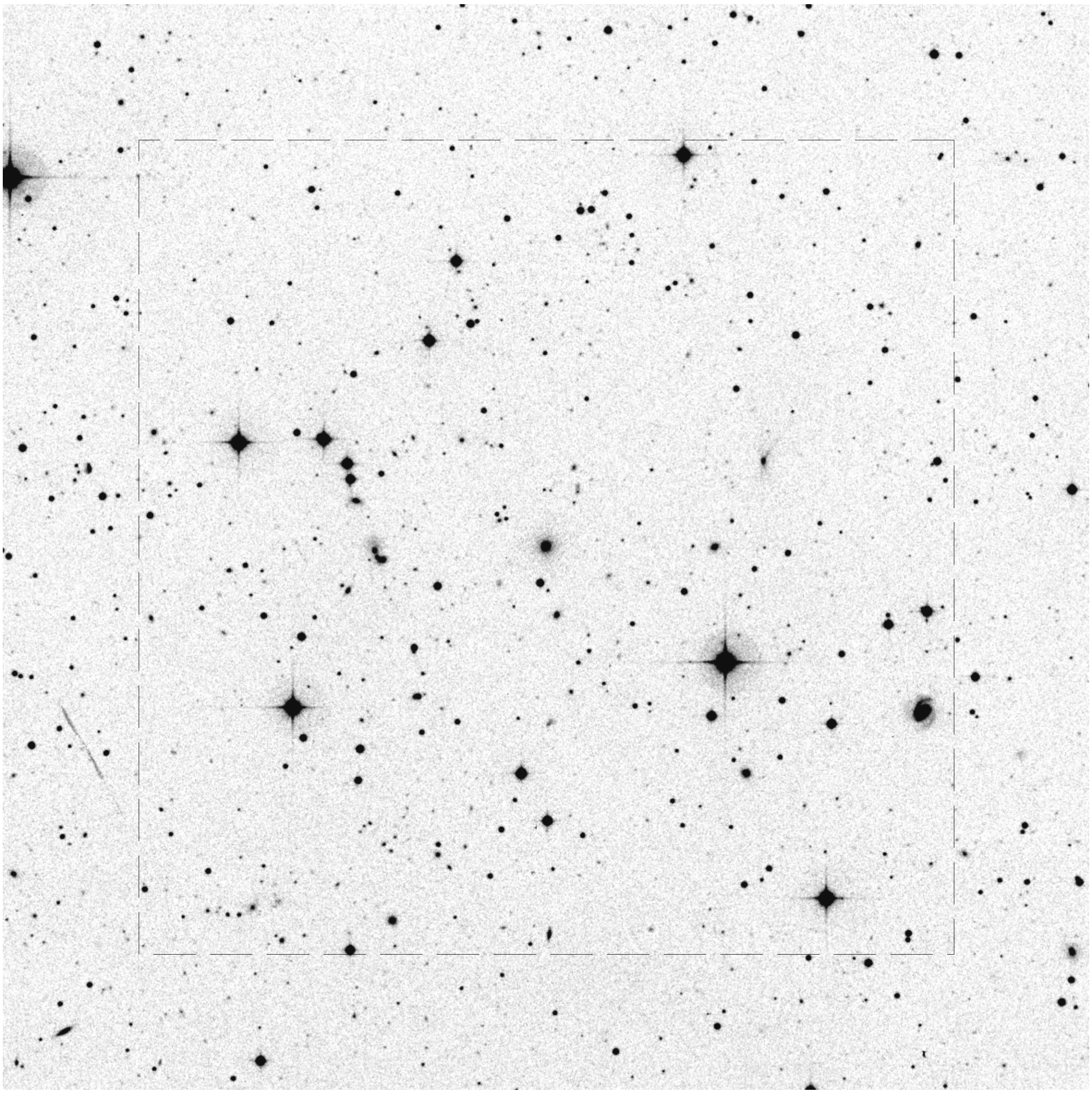


Figure 50: Focus field at RA ~ 1h.

A bright star in the neighbourhood produces a luminous arc in the field of view!

NGC 1647 $\alpha(J2000) = 4^h\ 45^m\ 51.52^s$ $\delta(J2000) = 19°\ 00'\ 30''$

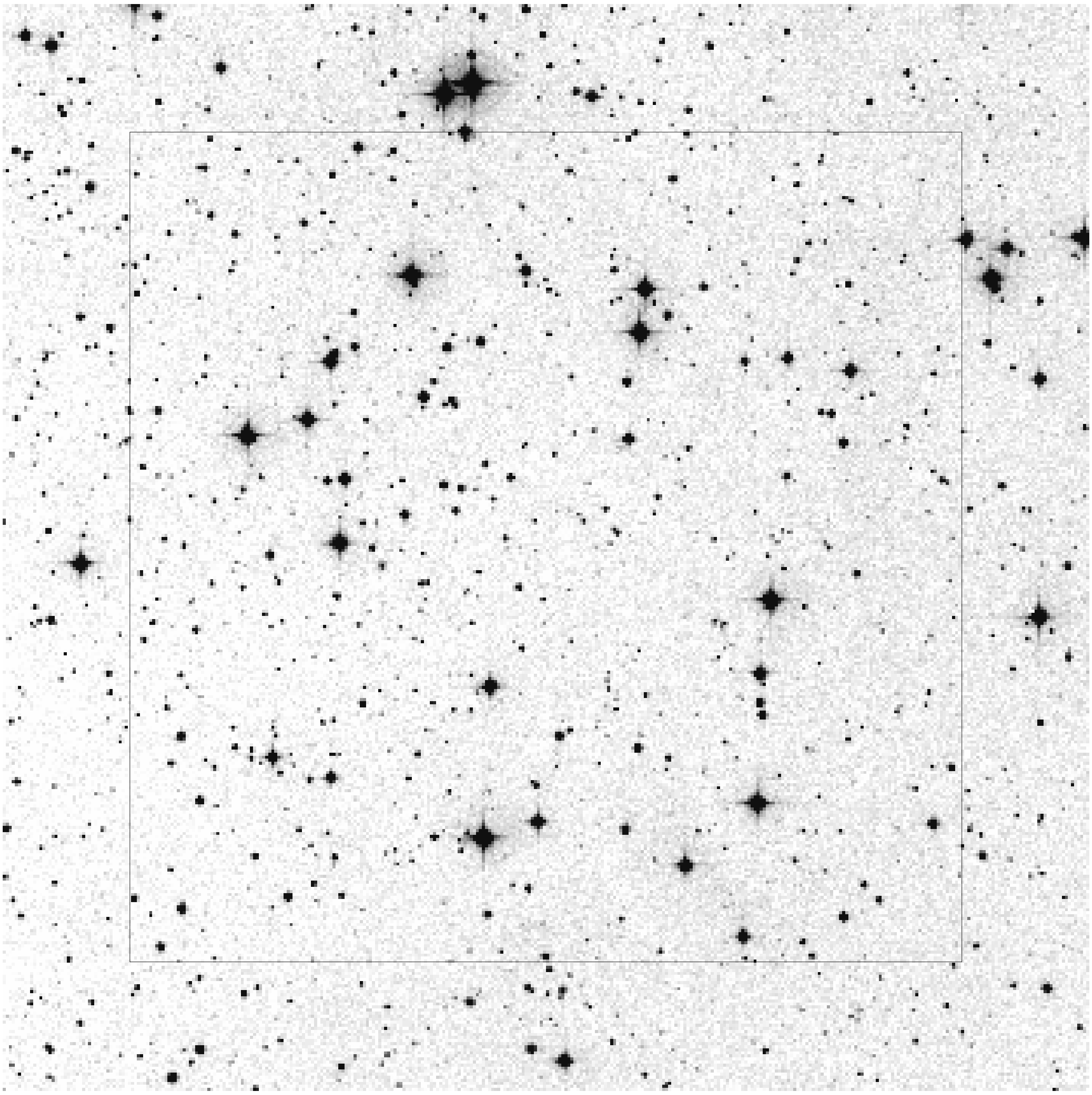


Figure 51: Focus field at RA ~ 5h. (NGC 1647)

M 67 α(J2000) = $8^h\ 51^m\ 15.79^s$ δ(J2000) = 11° 49' 8"

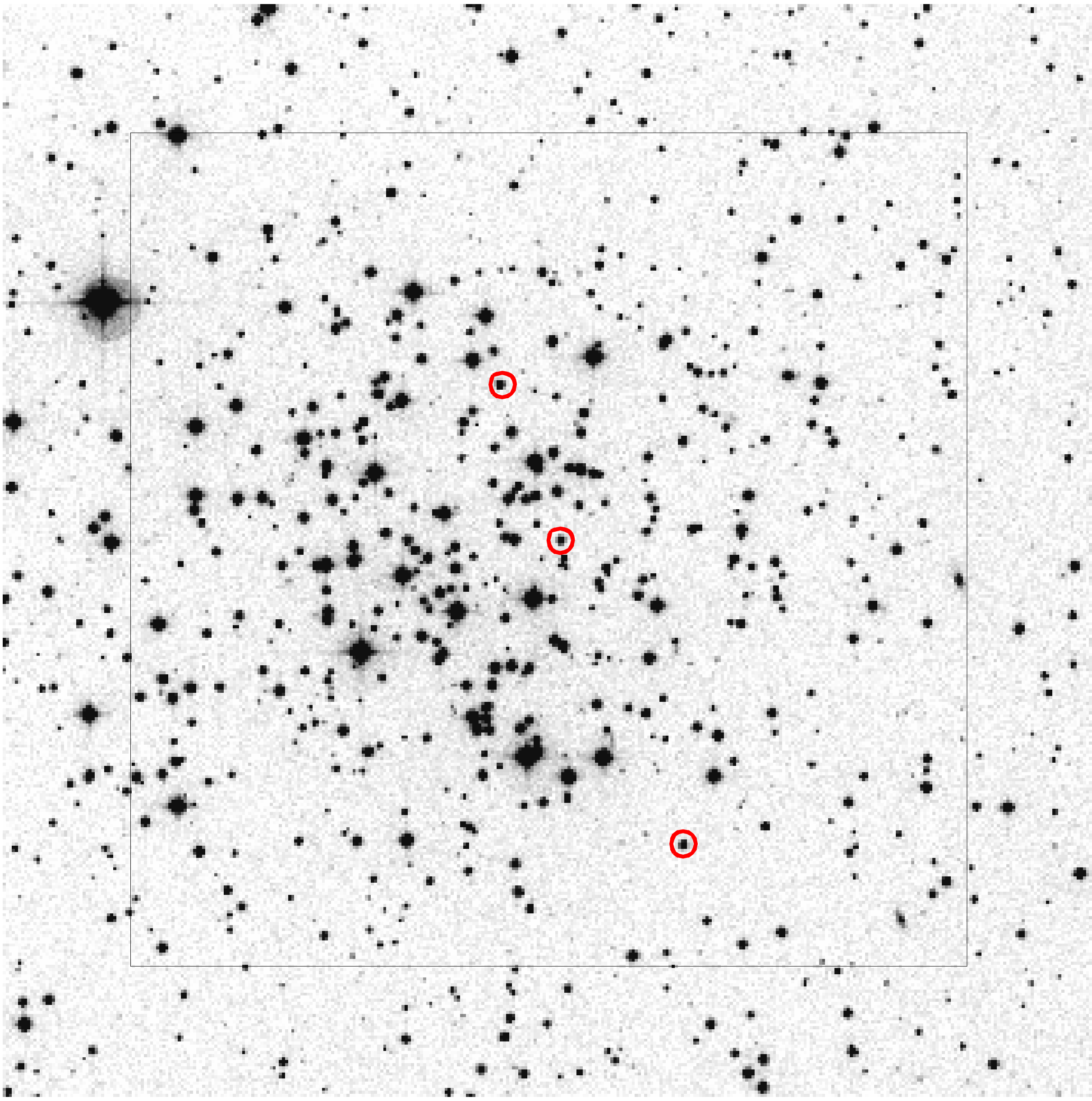


Figure 52: Focus field at RA ~ 9h (M67)

This field contains also 3 photometric standard stars (red circles from top to bottom):

	α (J2000)	δ (J2000)	K [mag]
M67 – IV- 27	8:51:19.57	11:52:9.0	12.3
M67 – IV- 08	8:51:15.13	11:49:19.3	12.6
M67 – I - 48	8:51:5.95	11:43:45.7	12.4

There are also more than 300 astrometric stars in this field from the M2000 catalogue.

Focus at 12h α(J2000) = $12^h\ 25^m\ 25.15^s$ δ(J2000) = 26° 59' 3"

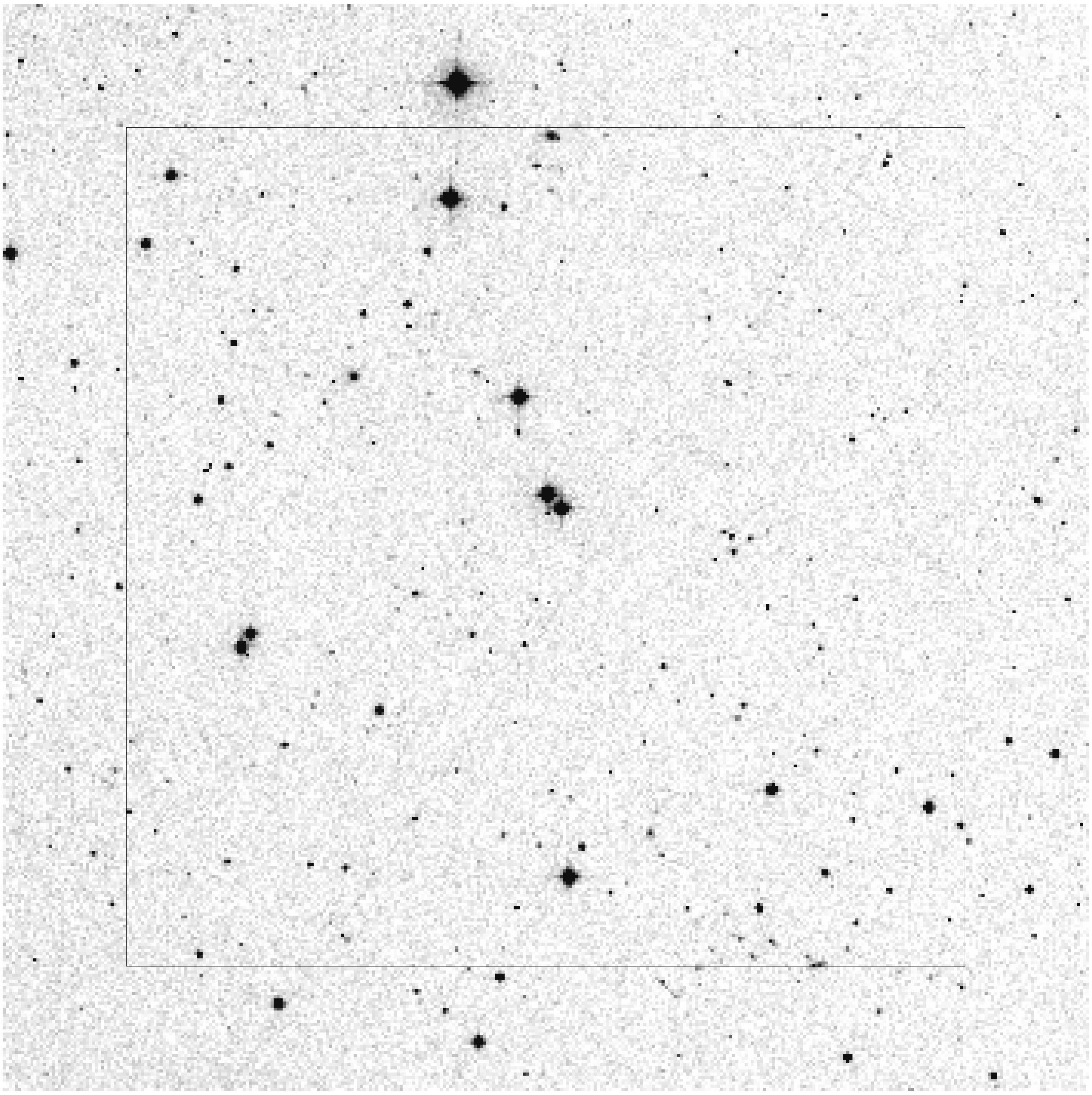


Figure 53: Focus field at RA ~ 12h.

Focus at 17h α(J2000) = 17^h 3^m 37.00^s δ(J2000) = 26° 59' 50"

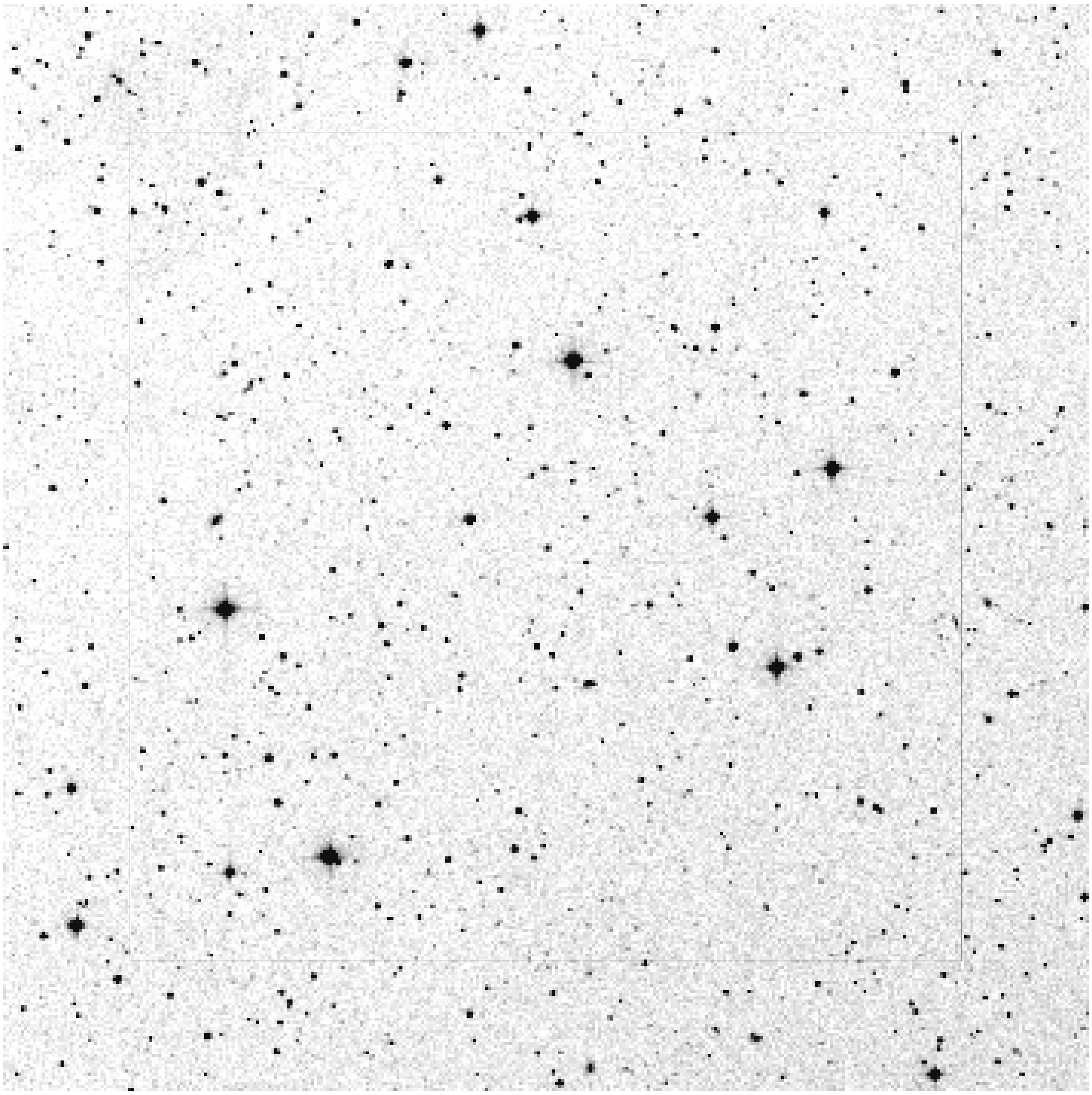


Figure 54: Focus field at RA ~ 17h

Focus at 22h a α(J2000) = $21^h\ 58^m\ 27.00^s$ δ(J2000) = 20° 17' 50"

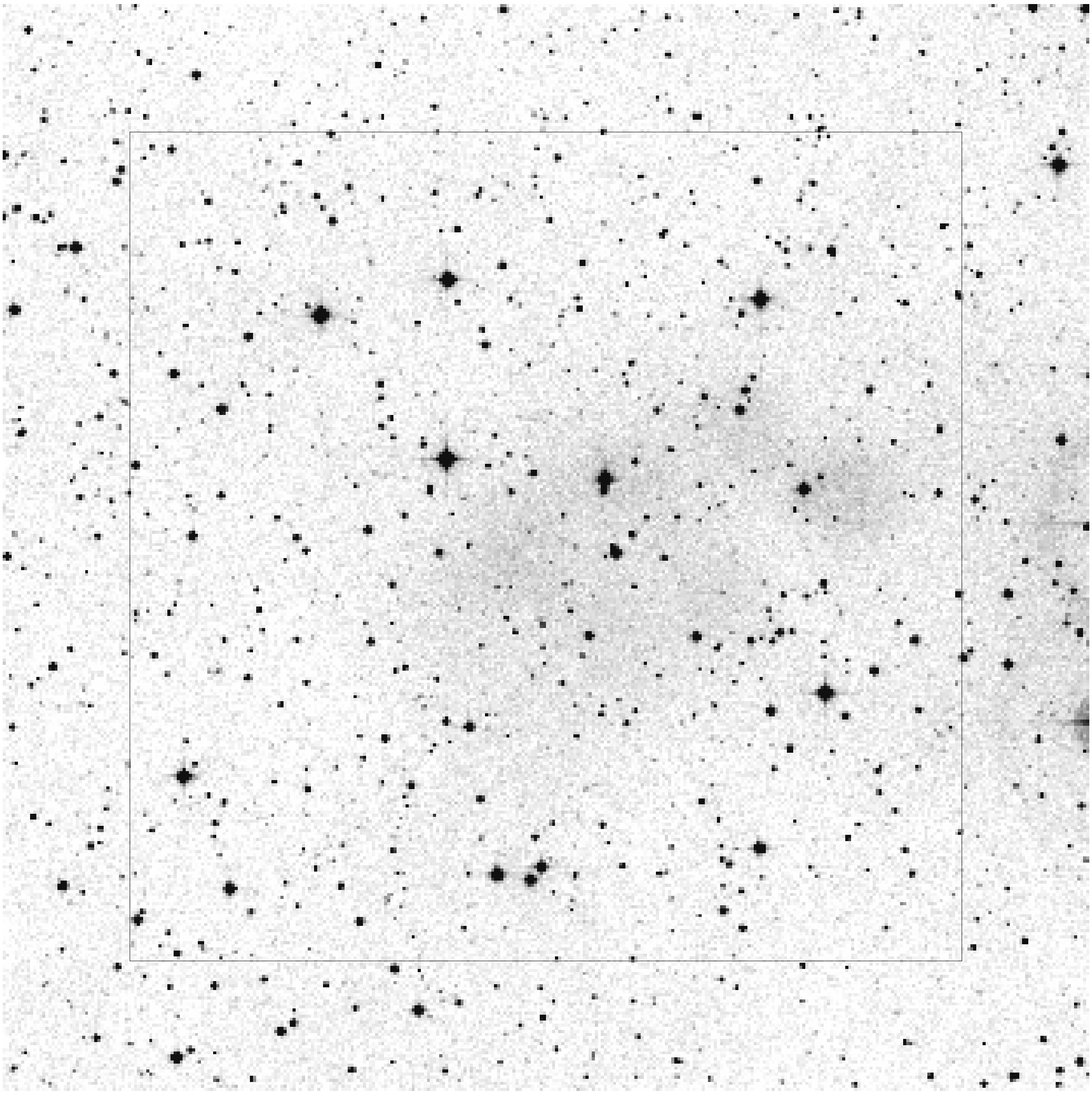
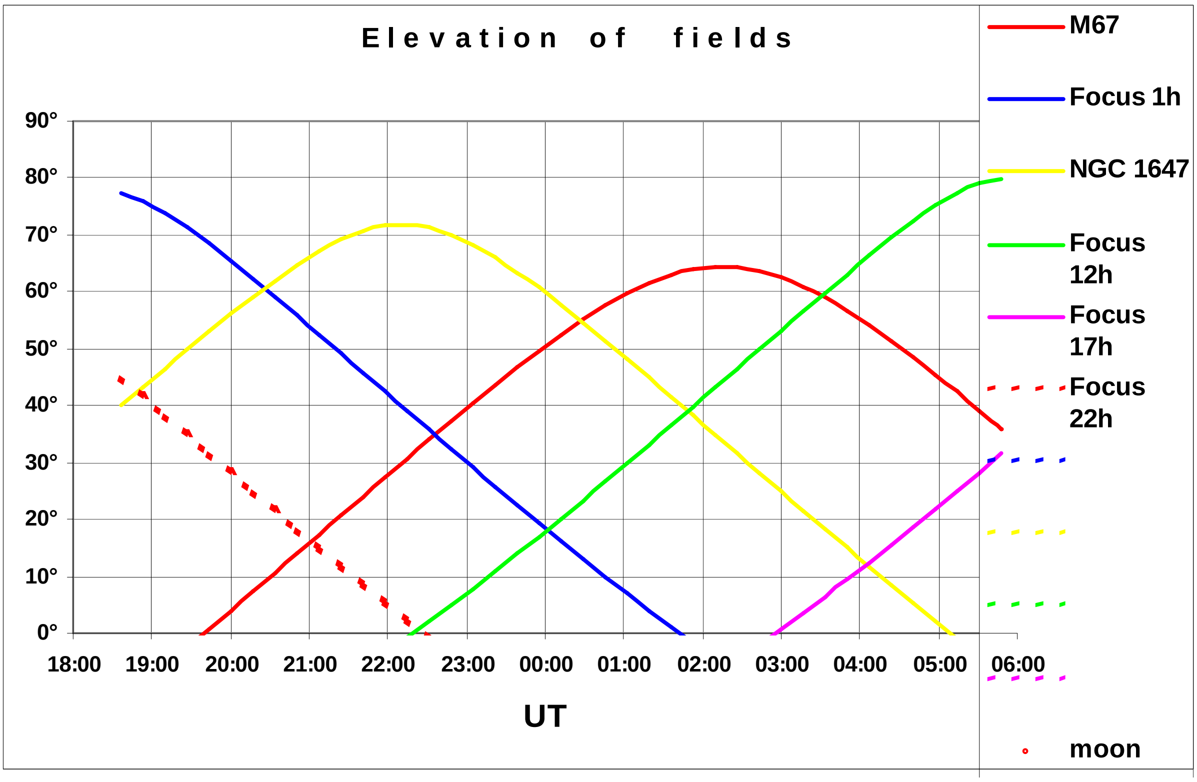


Figure 55: Focus field at RA ~ 22h

January



April

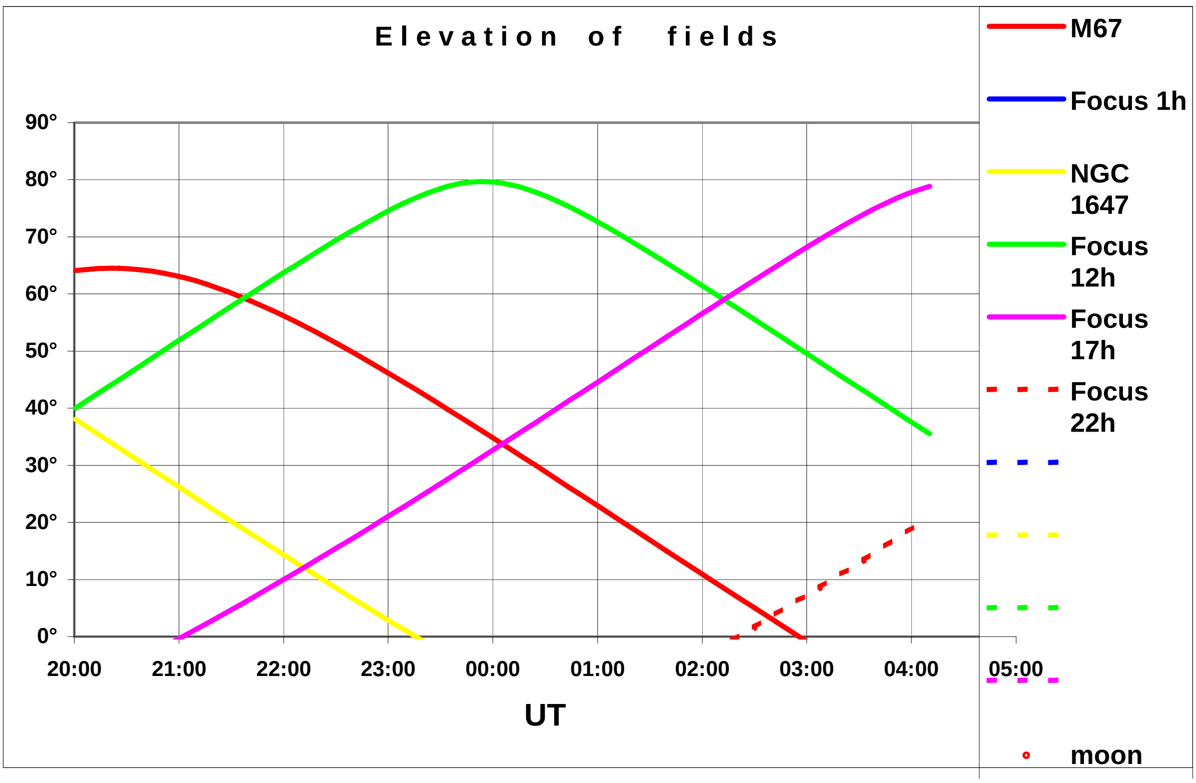
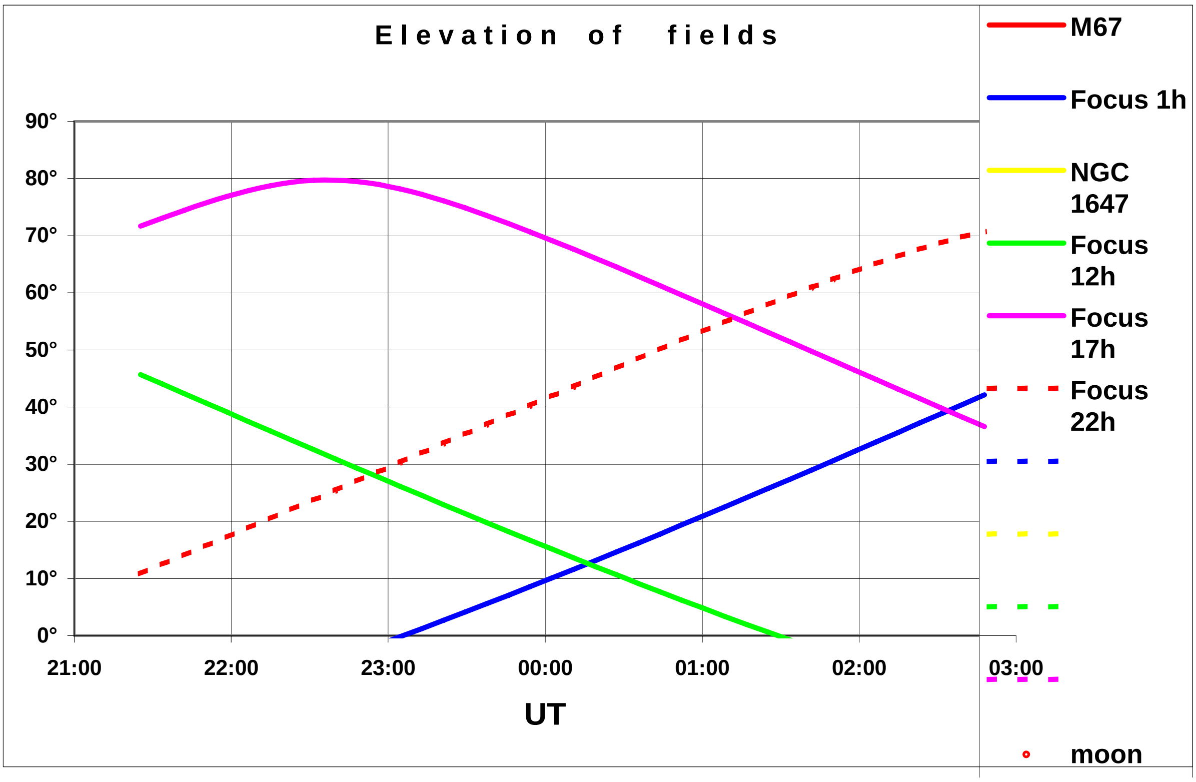


Figure 56: Elevation plots for focus fields (January and April)

July



October

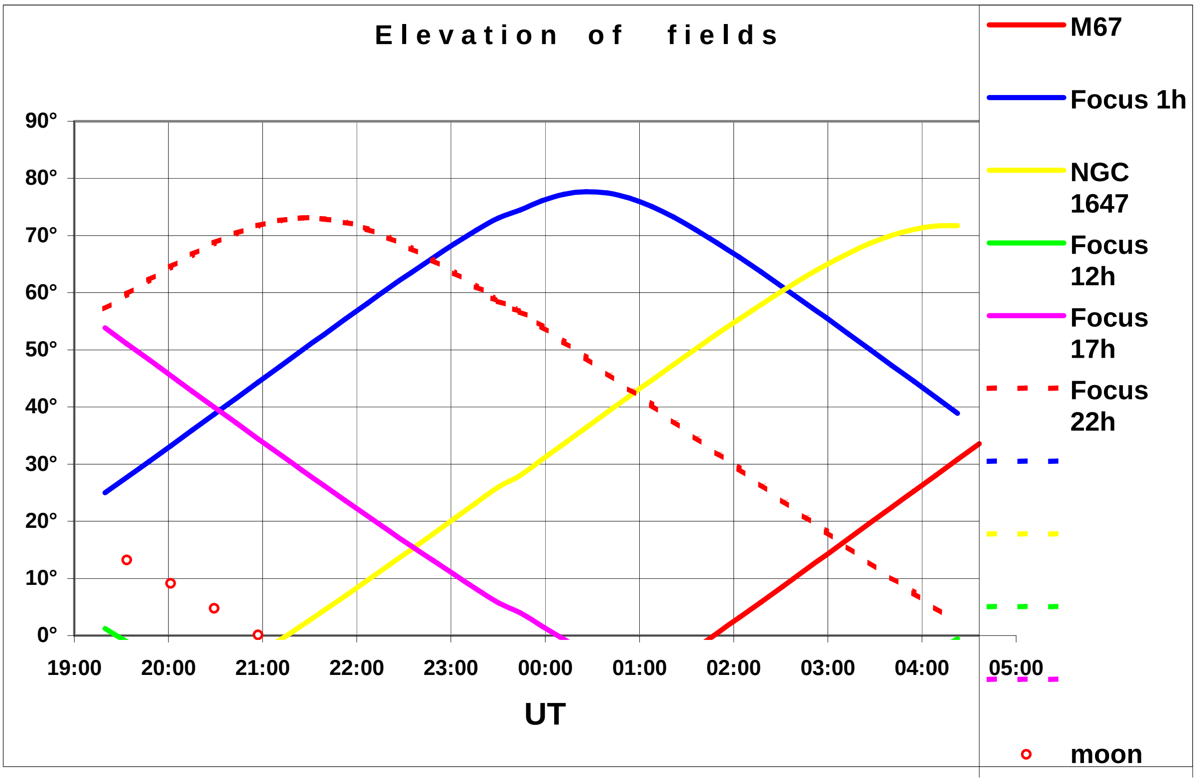


Figure 57: Elevation plots for focus fields (July and October)

Appendix 8 Astrometric fields

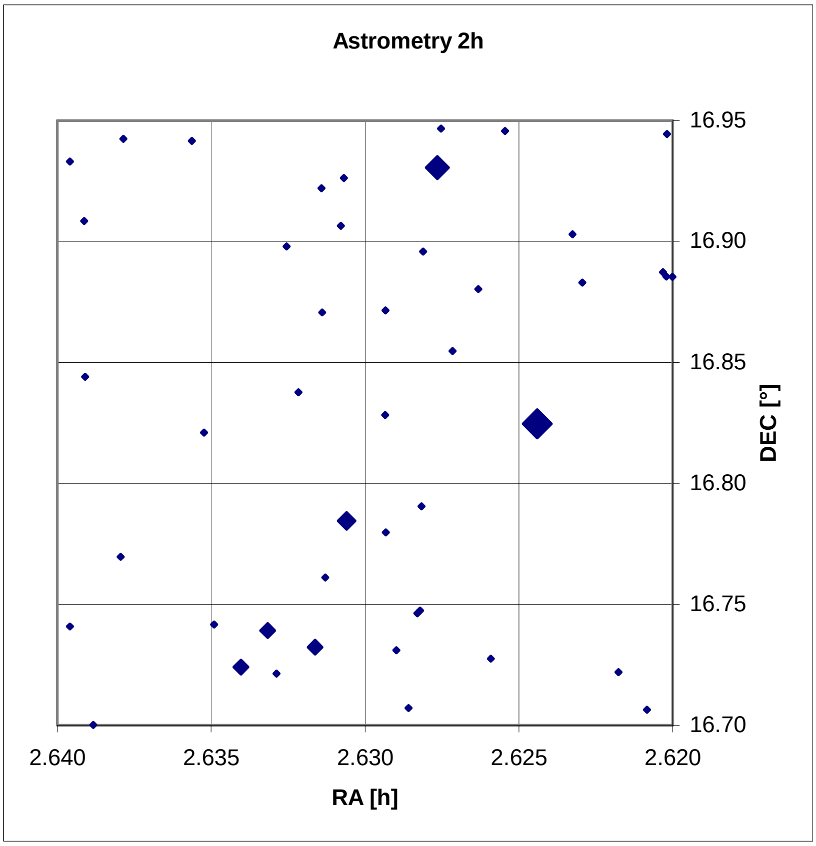
Astrometric data are provided to enable an easy check of the plate scale and a direct determination of the image rotation.

The fields were selected from the M2000 catalogue (Rapaport, Le Campion et al. 2001). These catalogue has a very recent epoch and is complete to V = 15.4^{mag}. Therefore many stars are found in each OMEGA2000 pointing. We thank the authors for supplying the data on CDROM. The tables with the positional information are available on fire35 as an html-file under /disk-a/o2k/MANUAL/Astrometrie_FC.html. For applications where also proper motions have to be taken into account, the data from the UCAC2 catalogue have to be used. These are also provided under the above path as Astrometrie_UCAC2.html.

name	RA [J2000]			DEC [J2000]			
2h	2	37	47.80	+	16	49	31.0
5h	4	49	4.75	+	13	5	20.0
M67	8	51	21.91	+	11	49	30.0
13h A	13	16	37.00	+	17	43	30.0
13h B	13	4	11.90	+	12	34	30.0
18h	17	41	55.92	+	14	43	0.0
22h	22	20	20.97	+	13	18	50.0

We supply finding charts of two types. One plots the astrometric reference stars with the brightest stars marked for easy cross-reference. The second chart is a copy from the red DSS-II. Both have a side length of about 16 arcmin.

We also provide elevation plots for four times in the year for optimal selection of the appropriate fields.



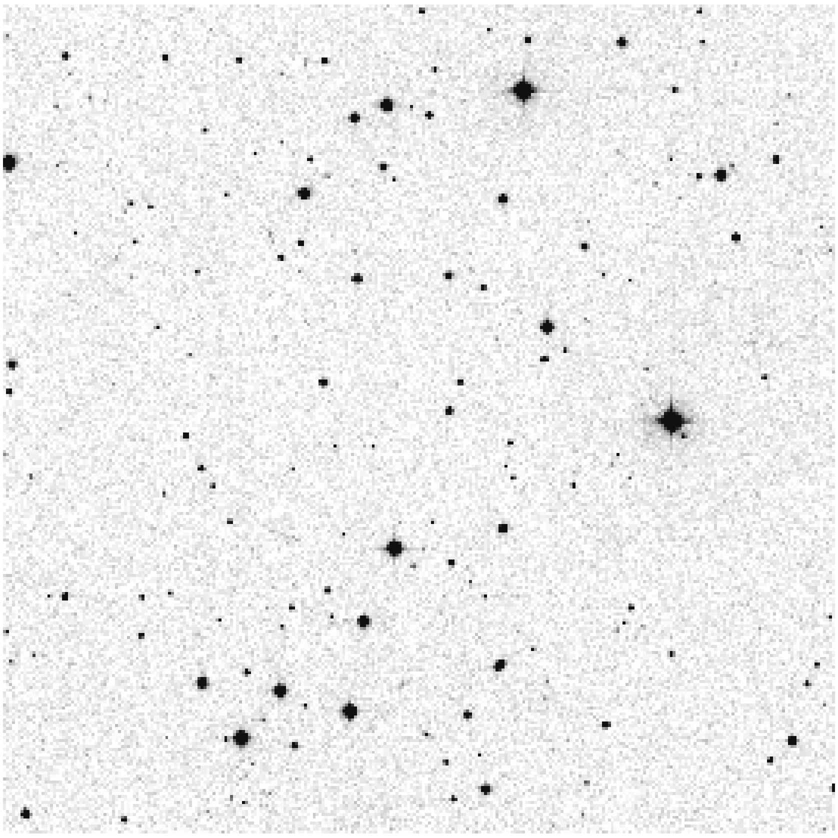
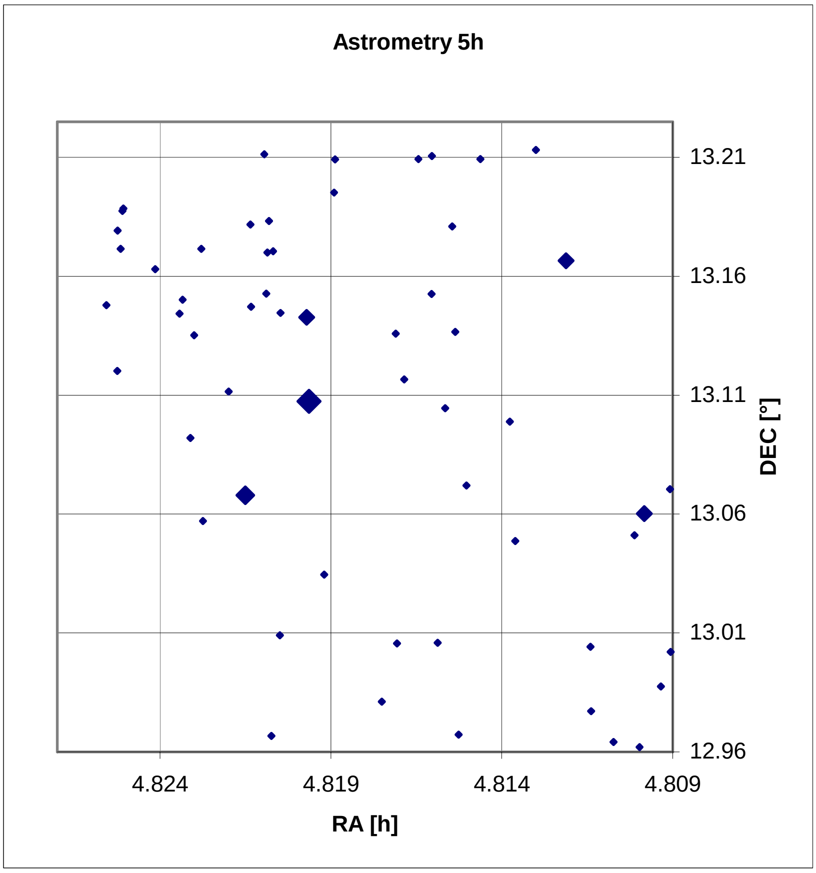


Figure 58: Astrometry field at RA ~ 2h, finding chart for astrometric stars from M2000.



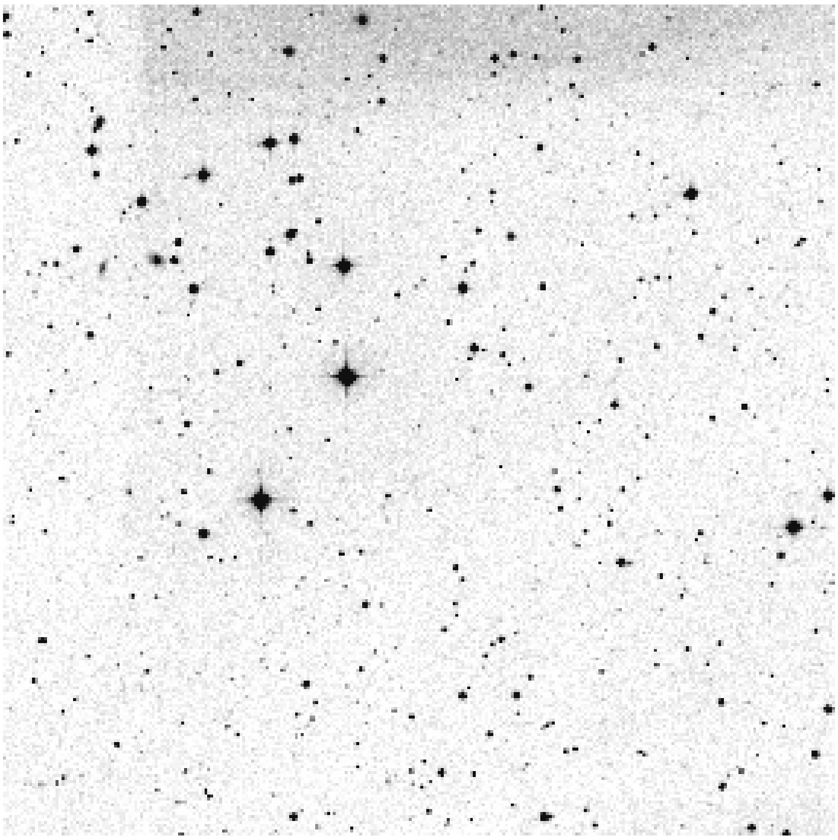
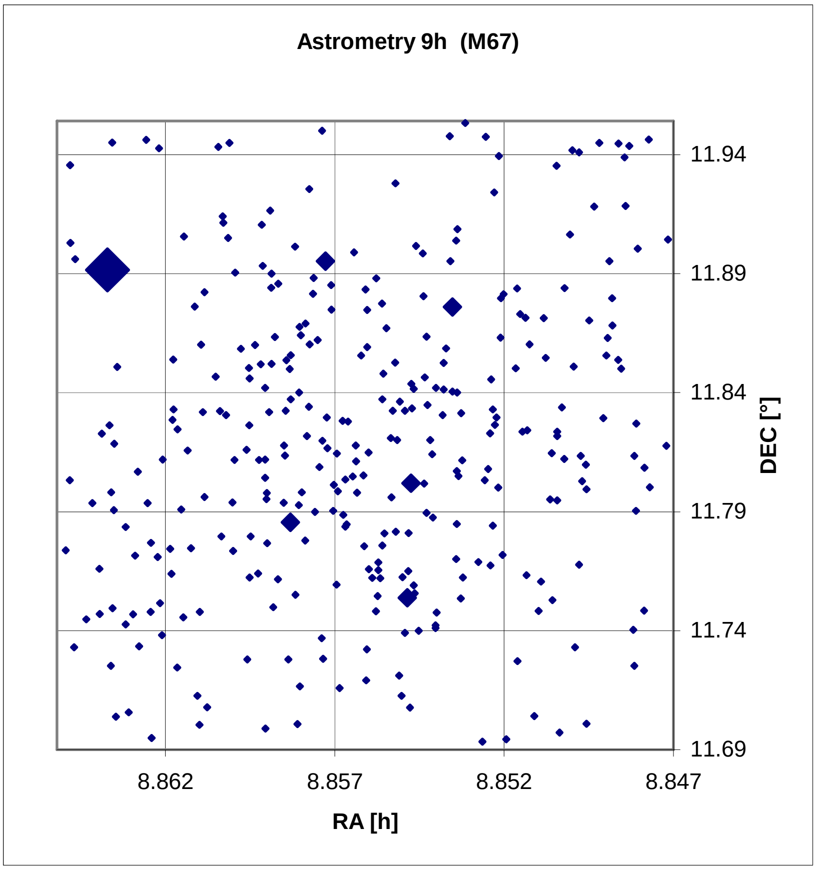


Figure 59: Astrometry field at RA ~ 5h, finding chart for astrometric stars from M2000.



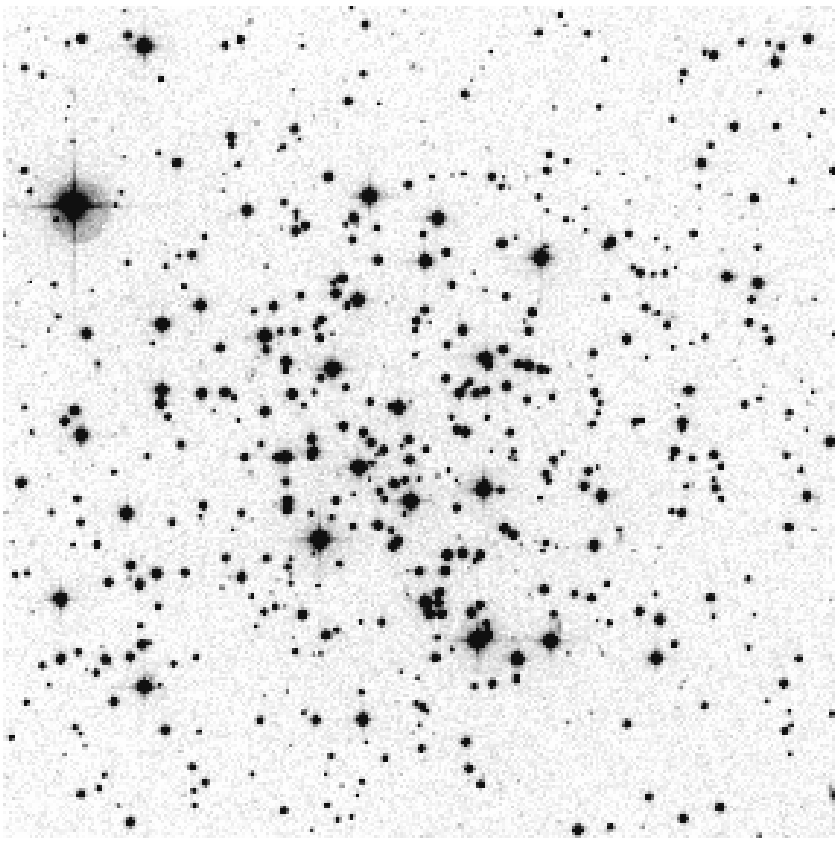
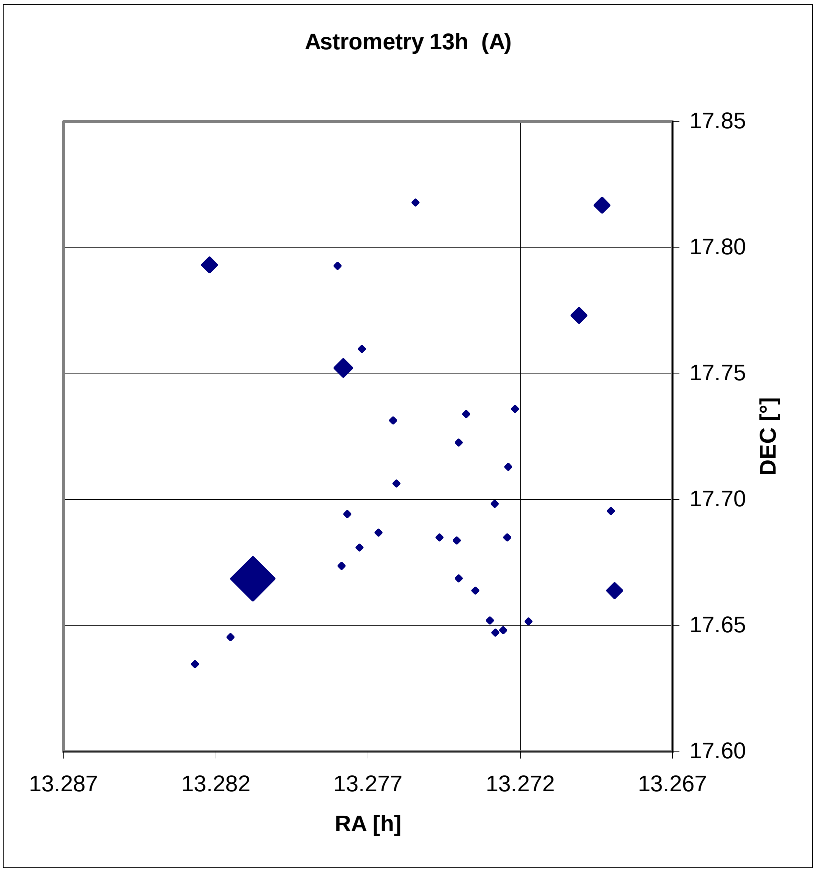


Figure 60: Astrometry field at RA ~ 9h, finding chart for astrometric stars from M2000.



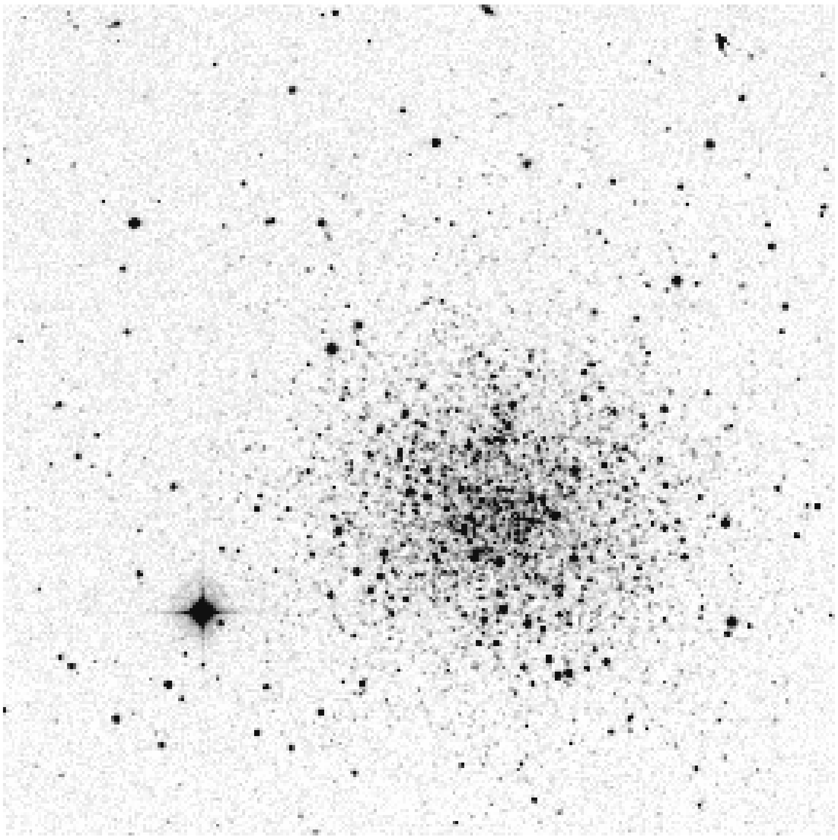
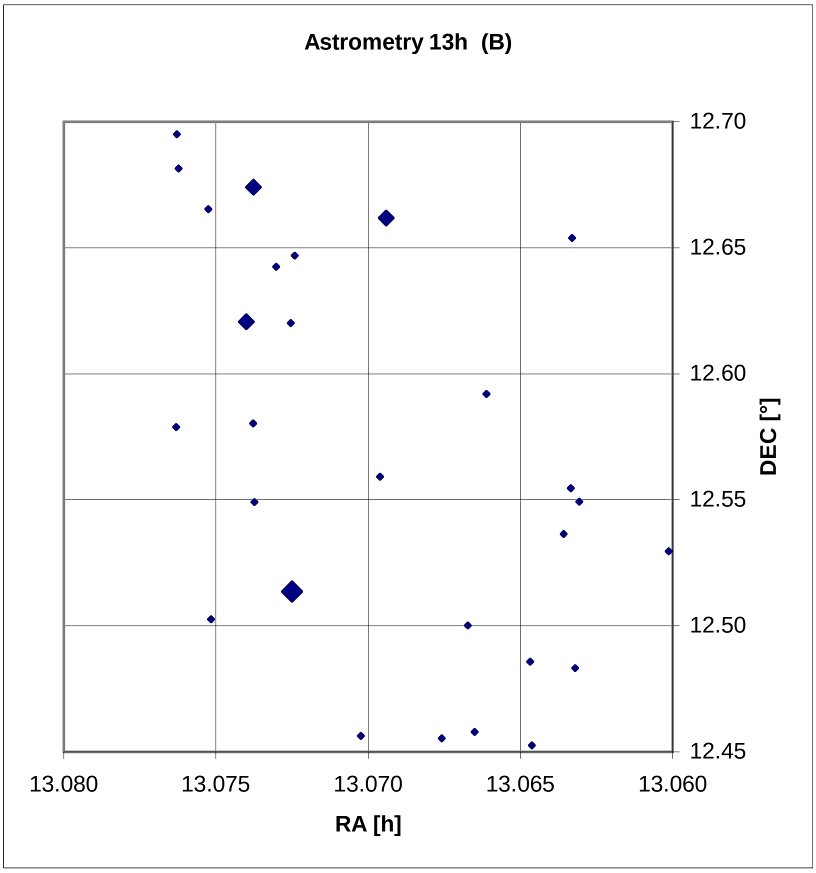


Figure 61: Astrometry field at RA ~ 13h, finding chart for astrometric stars from M2000.



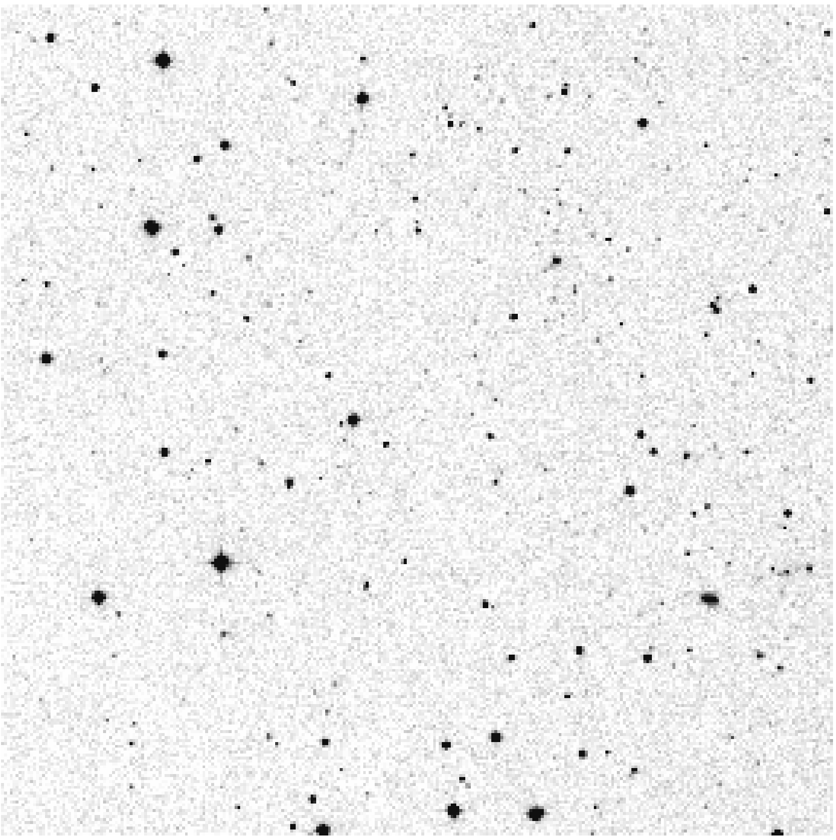
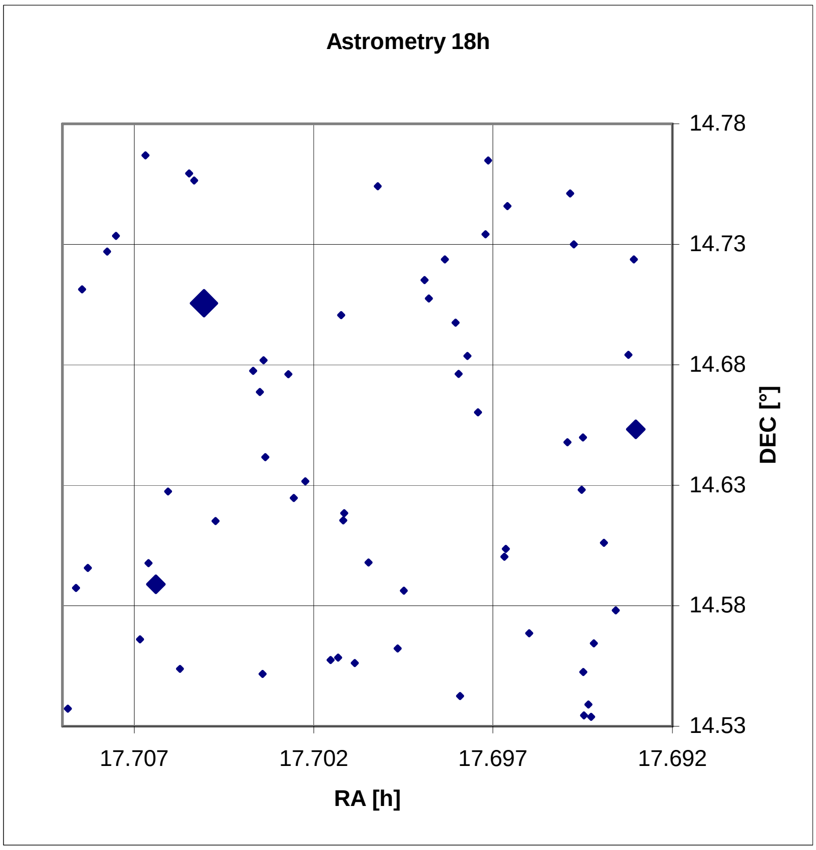


Figure 62: Astrometry field at RA ~ 13h, finding chart for astrometric stars from M2000.



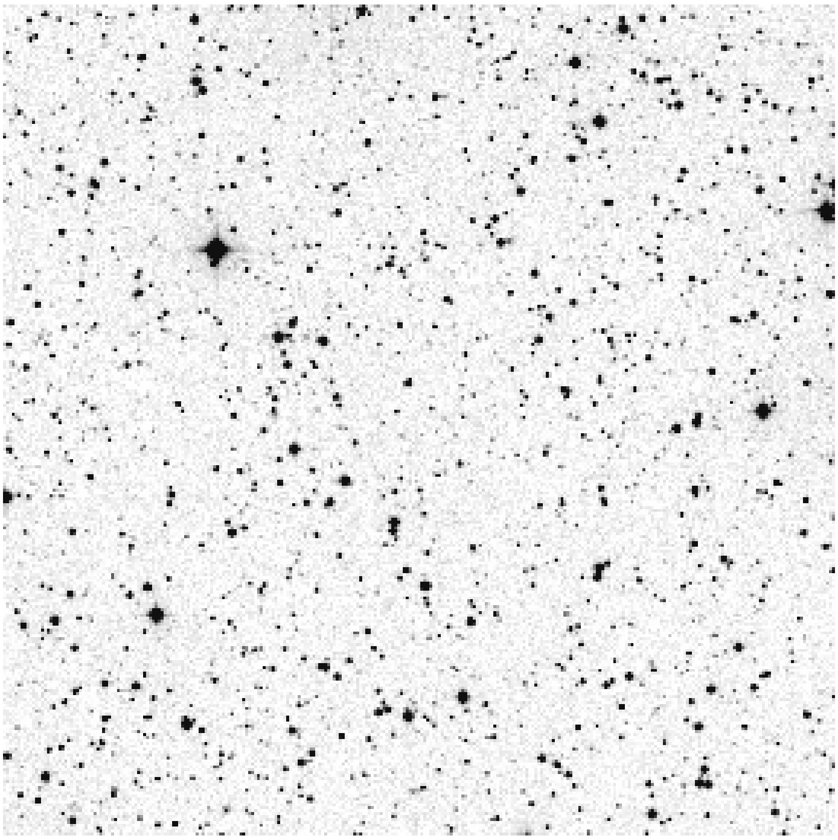
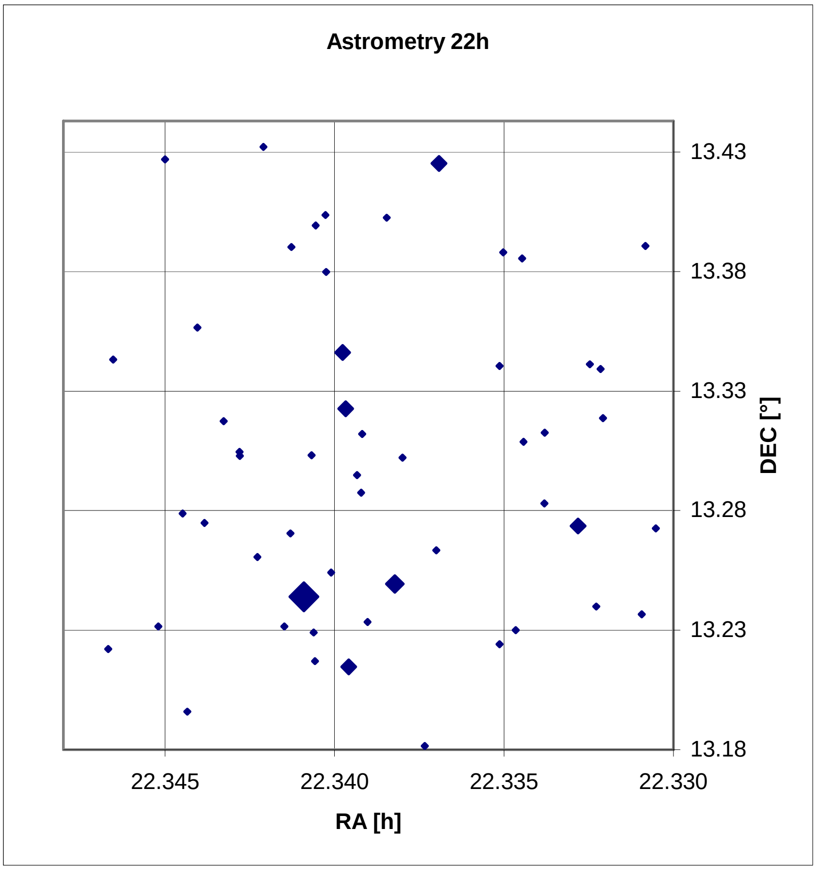


Figure 63: Astrometry field at RA ~ 18h, finding chart for astrometric stars from M2000.



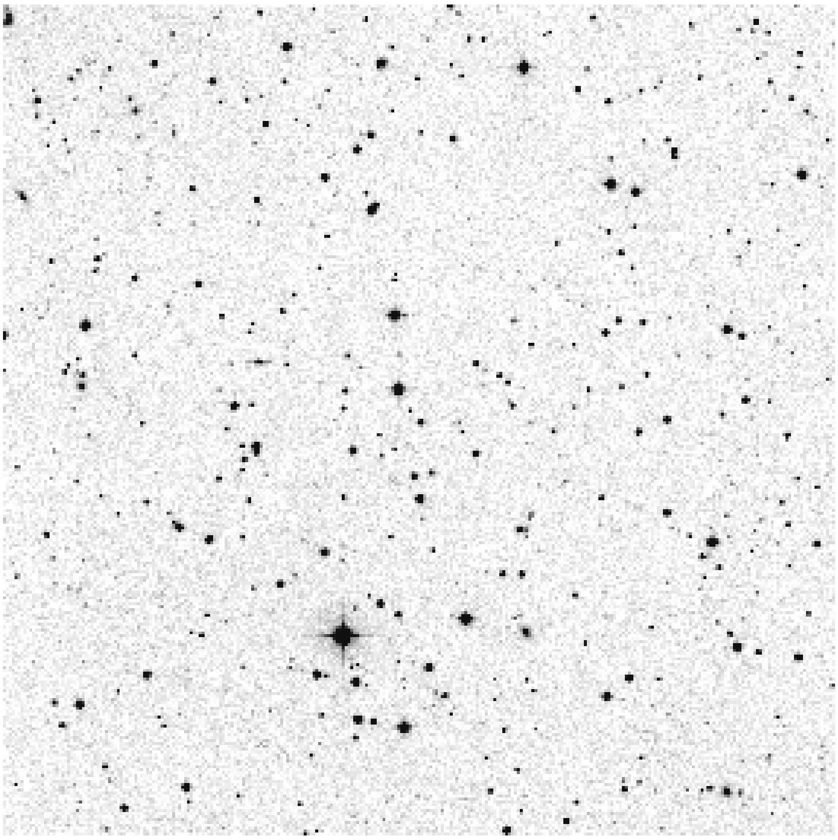
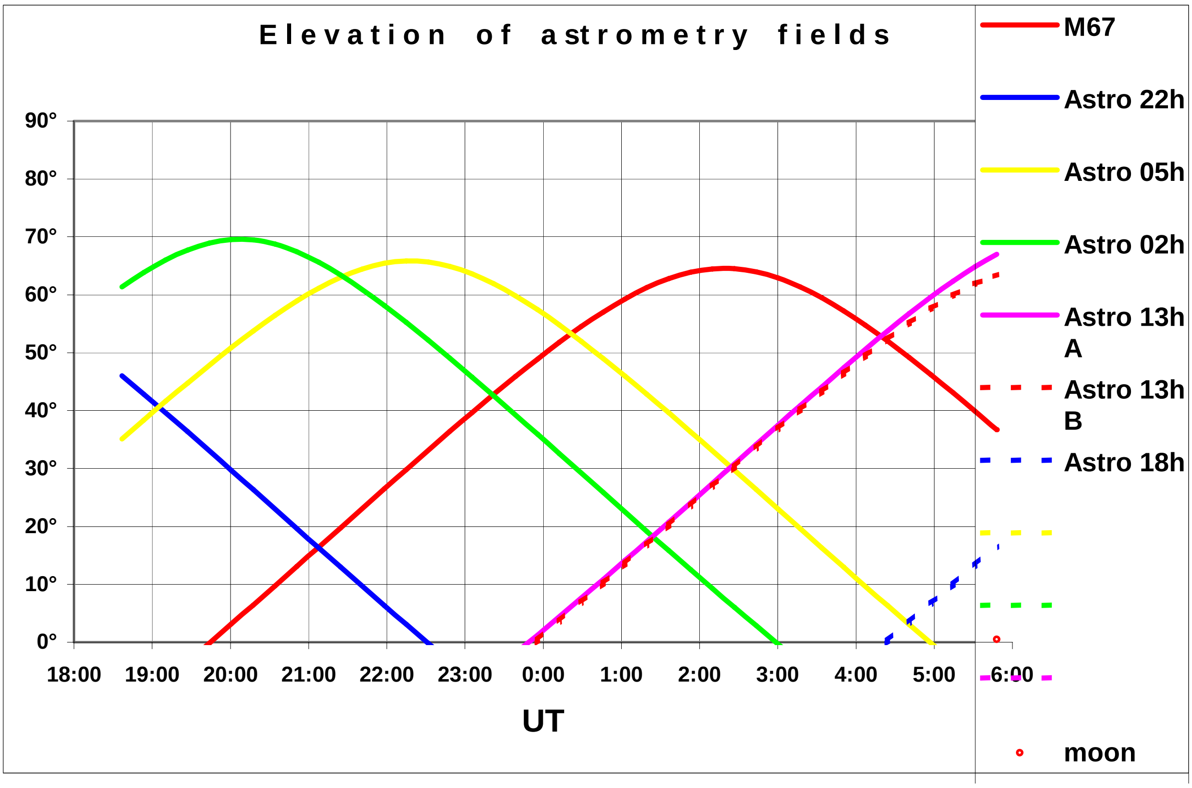


Figure 64: Astrometry field at RA ~ 22h, finding chart for astrometric stars from M2000.

January



April

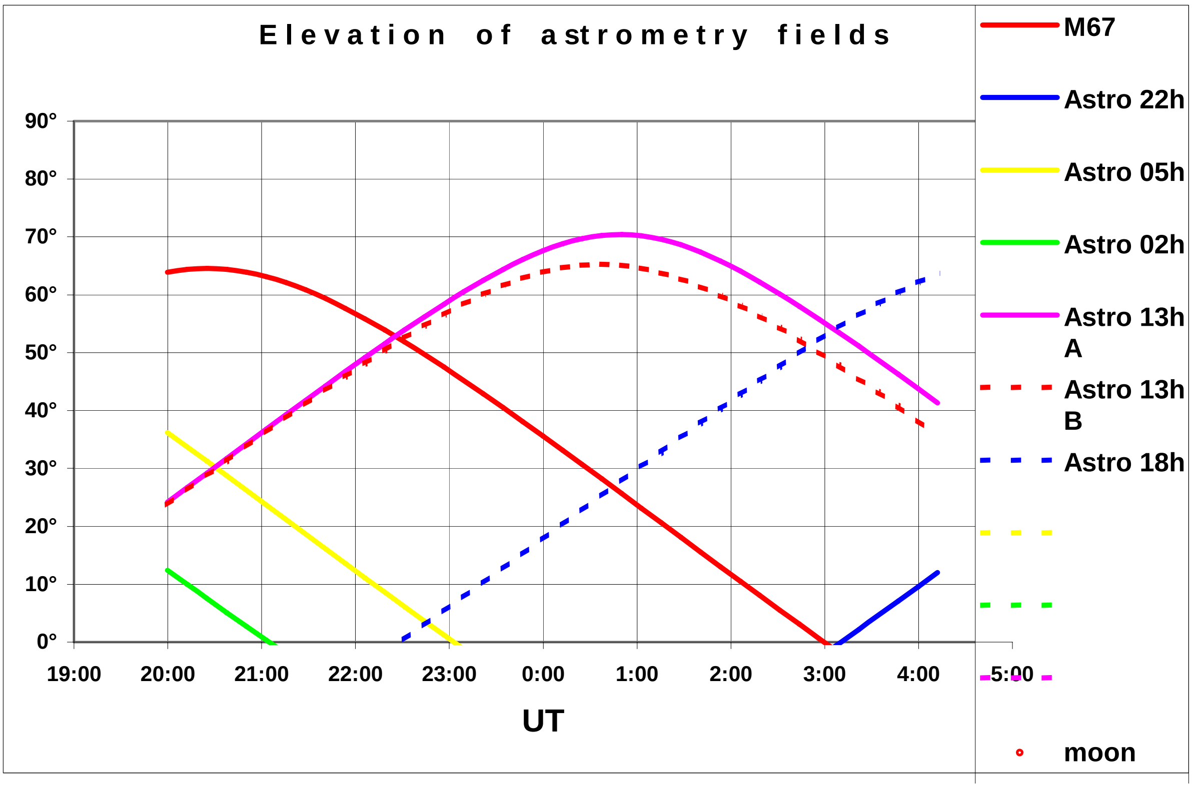
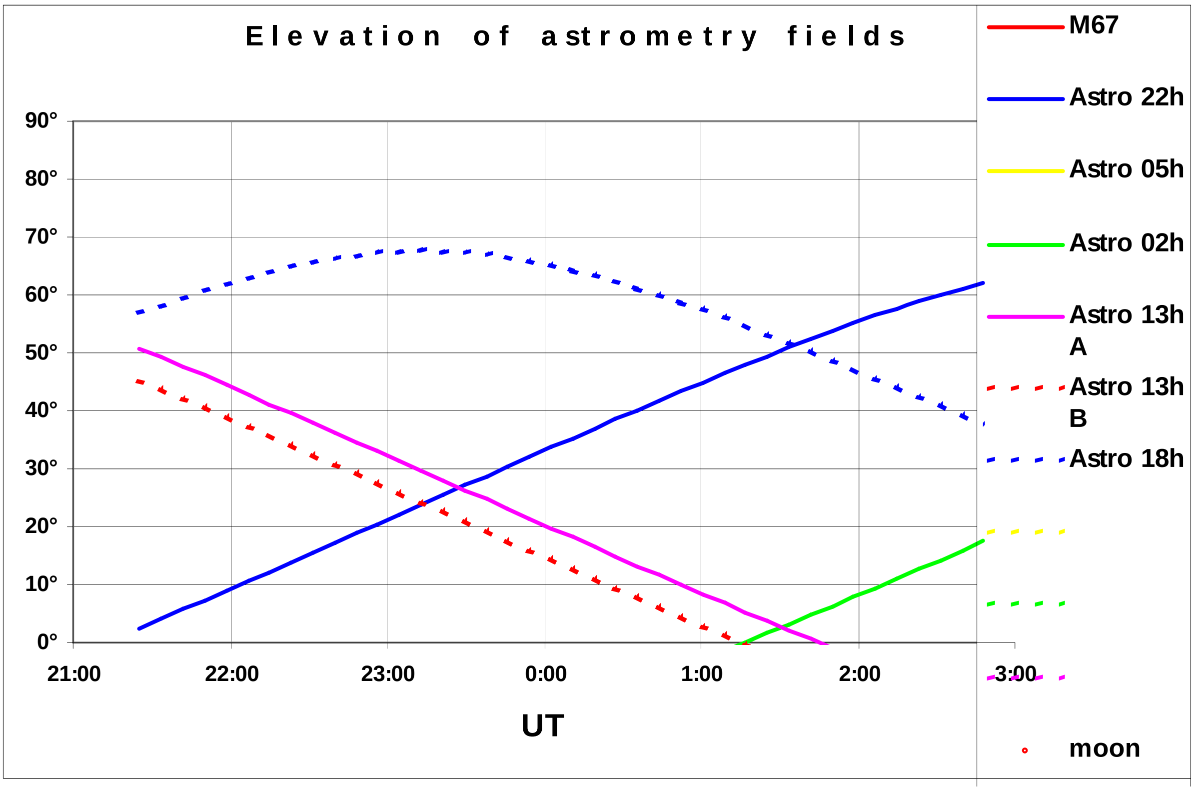


Figure 65: Elevation plots for the astrometry fields (January and April)

July



October

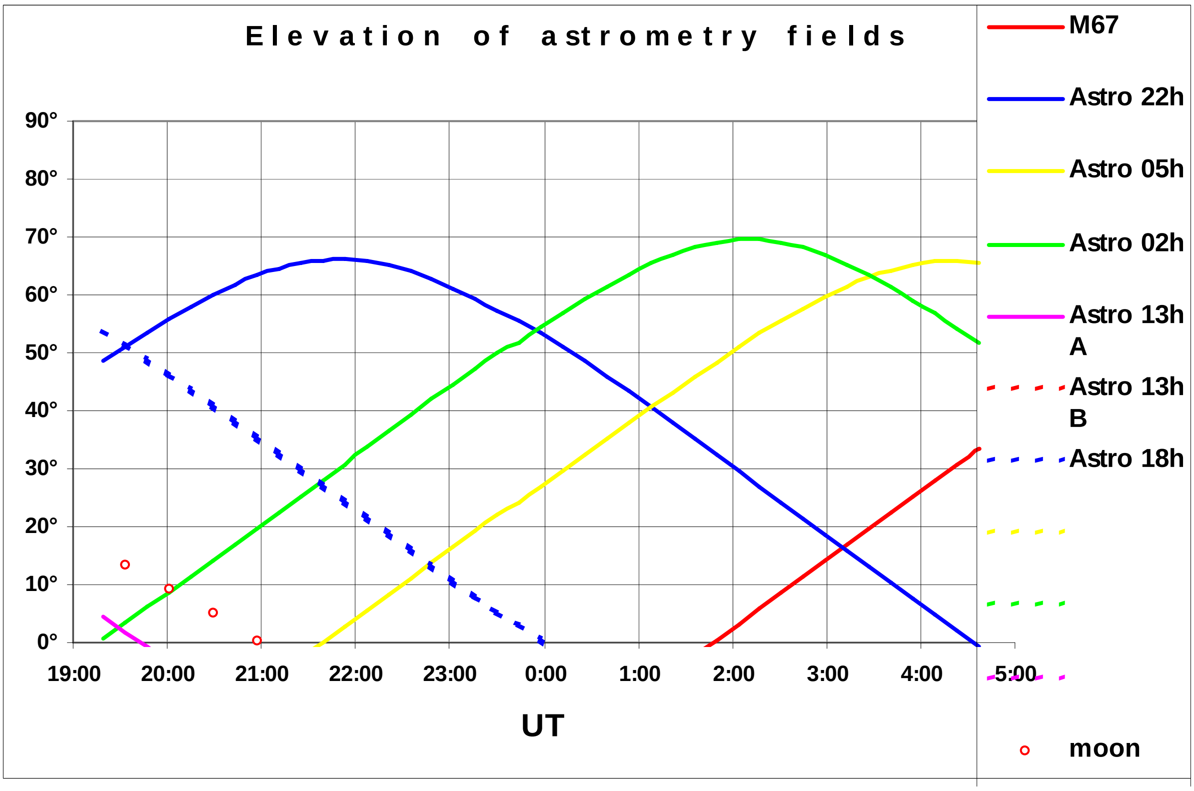


Figure 66: Elevation plots for the astrometry fields (July and October).

Appendix 9 Photometric zero points

Expected count rates for a star of 0mag with flat spectrum in f_ν :

filter	photons/cm²/s	counts/sec
J	2.37E+05	4.78E+09
H	1.10E+05	2.22E+09
Kp	8.25E+04	1.67E+09
K	9.32E+04	1.88E+09

Table 7: Photometric zero points (counts for zero magnitude).

Measured limiting magnitudes (provided by Sascha Quanz):

On source integration time 30min, seeing 1.1", 3σ-detections in all three filters give:

filter	limiting magnitude (2MASS system)
J	22.0
H	20.0
Ks	18.5

During the HIROCS project 3ksec integrations in H were obtained. The 5σ limiting magnitude was determined to be 21.3^{mag} (Vega) with seeing of 0.9".

Appendix 10 Photometric standard stars

The list of UKIRT faint standard stars as prepared by Dave Thompson is appended at the end of this manual. We plan to update the fainting charts as soon as possible.

For the astrometry fields (page 133) and focus fields (page 125) we plan to give J, H, Ks magnitudes from 2MASS for some representative objects.

Otherwise the 2MASS web page provides more data under

http://www.ipac.caltech.edu/2mass/releases/allsky/index.html

Appendix 11 LINUX PC as X-Terminal

OMEGA2000 is operated most conveniently from a dual-screen X-terminal. For this purpose we use a LINUX PC emulating an X-terminal. This way we ensure that we (almost) always do not run out of colours, despite the use of MIDAS display, netscape and acrobat etc.

To launch the terminal one has to log into the PC with the name o2klinux as follows:

User: `o2k`

Password: ask staff (same as on fire35)

Once the linux desktop is available you launch the terminal emulation as follows:

```
X :1 vt08 -query fire35
```

This connects directly to the fire35. You may also access other machines via the host chooser if you type instead

```
X :1 vt08 -indirect
```

It is possible to toggle between the LINUX desktop and the X-terminal with the function keys:

`Alt F8` : OMEGA2000 terminal

`Alt F7` : LINUX destop

To stop the additional xserver type `killall X`, to kill it give an additional `-9`.

On the LINUX PC besides the usual environment you will soon also have the possibility to work in a WINDOWS environment with Microsoft Office. Furthermore a DVD burner is available to backup your data.

Figure 67: Dual-screen X-terminal (to the right) operates the camera. The screen at left is for telescope operation.

Appendix 12 Basic MIDAS commands

To use the observing utilities (measuring seeing *etc.*) it is helpful to display a flatfielded image. Here are the basic steps for those not familiar with MIDAS (replace *italics* with actual names / values):.

Creating a normalized flatfield

`statistic  `*`filename`*`.fits`

displays the information on the frame statistics.

`compute `*`flat`*` = `*`filename`*`.fits / `*`median`*

Use the median from the statistics-command to normalize your image.
Output will be in BDF-format!

Flatfielding an image

`compute `*`test`*` = `*`filename`*`.fits / `*`flat`*

Display image on the screen

`load `*`test`*` sc=`*`2`*` ce=`*`1320,912`*` cuts=`*`3500,7500`*

This will display frame test with scale 2, centred on pixel [1320,912]. The lower and upper display levels ("cuts") are at 3500 and 7500, respectively. This assumes the image to be in BDF-format (see below).

To set the cut levels in terms of local sigma values use

`back/det`

This command displays the cursor box, which should be placed in a region of clean background (no stars, no bad pixels). The cuts are then calculated as median – 3σ, median+10σ (default). To set to other sigmas use

`back/det ? `*`low,high`*

Reading out pixel values from the display

`get/curs`

Measuring position and FWHM of an object

`center/gauss`

The default file type in MIDAS is the BDF-format. If you want to handle a raw (or pipeline produced) FITS-image you have to append the extension .fits to the filename.

The default command qualifier is `/ima`. So `comp` is equal to `comp/ima`.

For further information please refer to the MIDAS help GUI in the quicklook window of OMEGA2000.

Appendix 13 Glossary

To be filled in later!

Appendix 14 Acronyms used

CCD	charge coupled device
CDS	correlated double sampling
DSS	digital sky survey (see http://archive.eso.org/dss/dss)
FOV	field of view
FPA	focal plane array
GEIRS	Generic InfraRed Software

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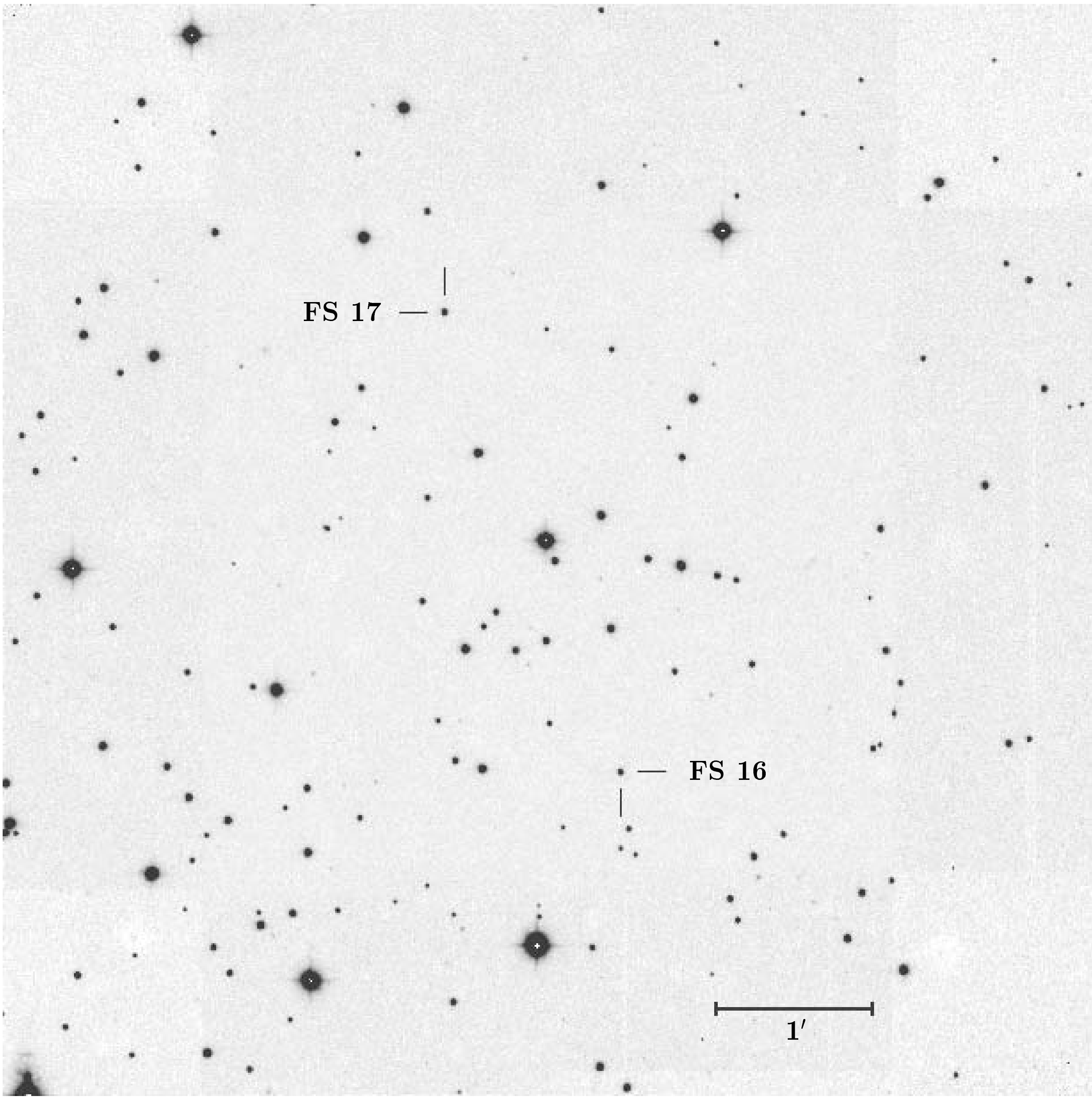
16. Subject index

UKIRT Faint Standard Stars

K-BAND FINDING CHARTS



Prepared by:
David Thompson
Max-Planck-Institut für Astronomie
Heidelberg, Germany

Introduction

The pointing on modern telescopes is typically good enough to place standard stars somewhere near the middle of the imaging arrays, so one can "point and shoot" and be reasonably assured that the standard will be observed. I still prefer to verify fields as I take data, which was the primary motivation in producing these finding charts. The construction of the Ω' prime-focus infrared camera for the Calar Alto 3.5m telescope added some additional incentive, as other existing flux standards (e.g. from Elias et al. 1982, AJ, 87, 1029) are too bright for this camera. Finally, enough copies of my loose-leaf stack of finding charts had been requested that it seemed reasonable to produce a more formal compilation...thus this work.

The standards for which these finding charts are provided come from the "UKIRT Faint Infrared Standards" list of Casali (1992, *JCMT UKIRT Newsletter*, 4, 33), and this is the source for most of the data which appears in the following table. The only "new" material here are the finding charts themselves (and, perhaps, the packaging).

The finding charts on the following pages were obtained through K$'$ filters with the MAGIC and Ω' infrared cameras at the Calar Alto 2.2m and 3.5m telescopes over the course of two years of observing. In several cases, identification of the field from Palomar Observatory Sky Survey (POSS) images was not so straightforward; the intrinsic colors of the stars can significantly alter the relative brightness of the different stars in any given field of view. In addition, proper motions can change the relative positions over the 50 years since the first POSS was produced. It is hoped that these finding charts will thus be useful to the infrared observers.

David Thompson
19 February 1997

Cover: This image of FS16 and FS17 shows the field of view of the Ω' camera on the Calar Alto 3.5m telescope, 6.8 arcminutes square, produced from five offset 5-second images.

UKIRT Faint IR Standard Stars

Name	Other	α_{1950}	δ_{1950}	m_K	Notes
FS01	G158-100	00:31:22.7	−12:24:29	12.98	(J-K) +0.46 DG-K
FS02	SA92-342	00:52:36.0	+00:26:58	10.47	(J-K) +0.25
FS03	Feige 1	01:01:46.6	+03:57:34	12.82	(J-K) −0.22 sdB
FS04	SA93-317	01:52:03.7	+00:28:20	10.26	(J-K) +0.29
FS05	Feige 16	01:52:04.7	−07:00:47	12.34	(J-K) −0.01 A0
FS06	Feige 22	02:27:39.2	+05:02:34	13.37	(J-K) −0.14 DA3
FS07	SA94-242	02:54:47.2	+00:06:39	10.94	(J-K) +0.17
FS08[1]	SA94-251	02:55:12.9	+00:04:04	8.31	(J-K) +0.77 K2
FS09[1]	SA94-702	02:55:38.8	+00:58:54	8.27	(J-K) +0.88
FS10[2]	GD50	03:46:17.4	−01:07:38	14.92	(J-K) −0.17 DA2
FS11[2]	SA96-83	04:50:25.4	−00:19:34	11.28	(J-K) +0.08
FS12	GD71	05:49:34.8	+15:52:37	13.90	(J-K) −0.22 DA1
FS13	SA97-249	05:54:33.8	+00:00:53	10.14	(J-K) +0.38
FS14[2]	Rubin 149	07:21:41.2	−00:27:10	14.26	(J-K) −0.15 O9-B2p
FS15	M67-I-48	08:48:21.9	+11:55:02	12.36	(J-K) +0.42
FS16	M67-IV-8	08:48:31.0	+12:00:36	12.63	(J-K) +0.34
FS17	M67-IV-27	08:48:35.4	+12:03:26	12.27	(J-K) +0.41
FS18	SA100-280	08:51:02.1	−00:25:14	10.52	(J-K) +0.29
FS19	G162-66	10:31:14.5	−11:26:08	13.80	(J-K) −0.23 DA2
FS20	G163-50	11:05:27.6	−04:53:04	13.47	(J-K) −0.12 DA4
FS21	GD140	11:34:27.6	+30:04:35	13.13	(J-K) −0.18 DA
FS33	GD153	12:54:35.1	+22:18:08	14.24	(J-K) −0.22 DA
FS23	M3-193	13:39:25.7	+28:44:59	12.37	(J-K) +0.62
FS24[3]	SA106-1024	14:37:33.3	+00:14:36	10.75	(J-K) +0.15 Var?
FS25	SA107-1006	15:35:59.9	+00:24:03	9.76	(J-K) +0.48
FS26[1]	SA108-475	16:34:26.3	−00:28:39	7.97	(J-K) +0.86
FS27	M13-A14	16:38:54.2	+36:26:56	13.12	(J-K) +0.37
FS28	SA109-71	17:41:32.5	−00:23:44	10.60	(J-K) +0.15
FS35	G21-15	18:24:44.5	+04:01:17	11.76	(J-K) +0.47 DA
FS34	EG141	20:39:41.9	−20:15:21	12.99	(J-K) −0.17 DA
FS29	G93-48	21:49:53.0	+02:09:16	13.35	(J-K) −0.17 DA3
FS30	SA114-750	22:39:11.3	+00:56:55	12.02	(J-K) −0.09
FS31	GD246	23:09:50.4	+10:30:46	14.04	(J-K) −0.24 DA1
FS32	Feige 108	23:13:38.2	−02:06:58	13.66	(J-K) −0.21 DA

[1] Too bright for Ω'.

[2] Current ID not positive.

[3] Variable star?

Finding Charts

All of the following images are printed with standard astronomical orientation: north is up, and east to the left. The images are roughly 4 arcminutes square; a scale bar of 1 arcminute length provides a reference in each image. The UKIRT faint standard star in each image is indicated with tick marks.

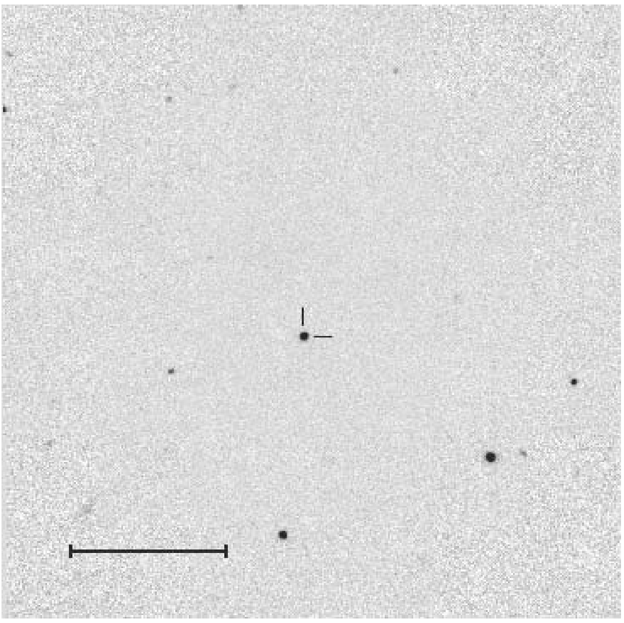
I have thus far been unable to positively identify the fields of FS10, FS11, and FS14, so I would not recommend their use at this time. In addition, a quick search through SIMBAD revealed that FS24 (SA106-1024) was listed as a variable star. In the several observations I have of this standard, the magnitude appeared to be relatively constant and at the magnitude given in Casali (1992), but one should probably avoid using this star for accurate flux calibrations of infrared data.

The finding charts are arranged in **numerical order** by their "faint standard" number. This arrangement should make it easier to find the images quickly.

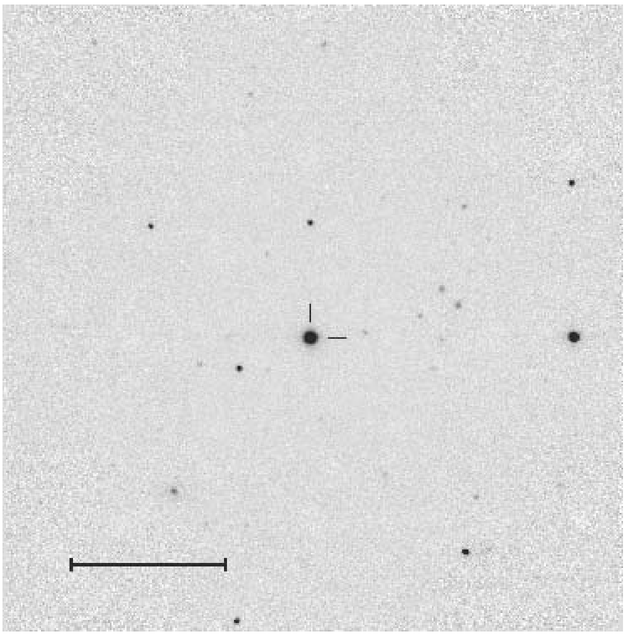
This version is missing finding charts for FS18 and FS26. I have the data for these fields, I just have to reduce it...

For users of Ω' at Calar Alto, the standards FS08, FS09, FS26, and possibly FS25 (depending on the seeing) are too bright to be used as standards - they saturate in the minimum exposure time for this camera.

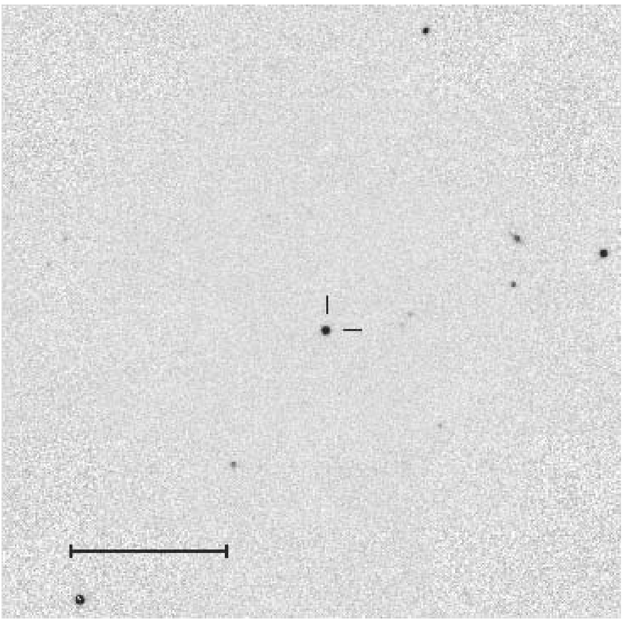
FS 01



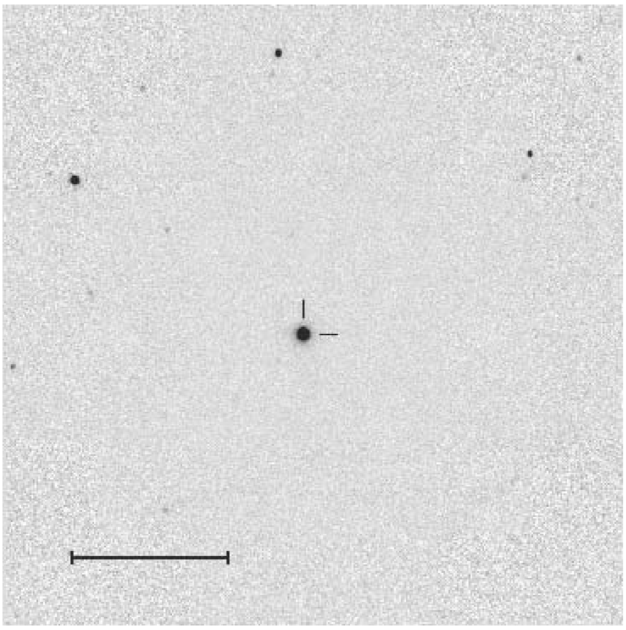
FS 02



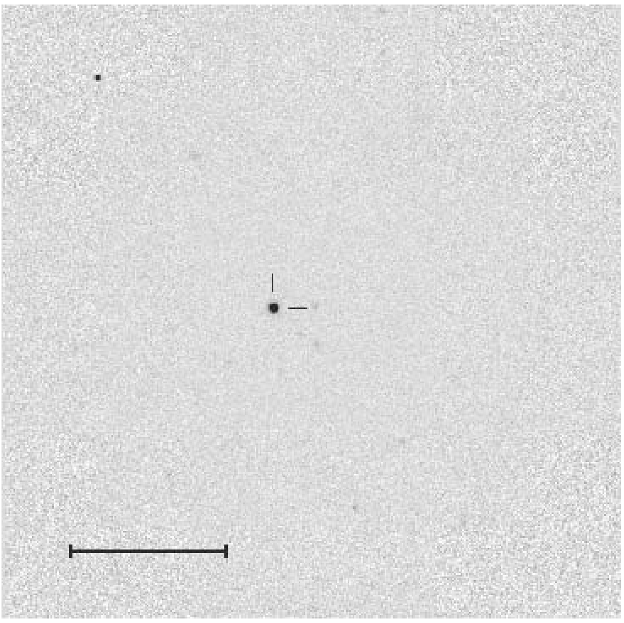
FS 03



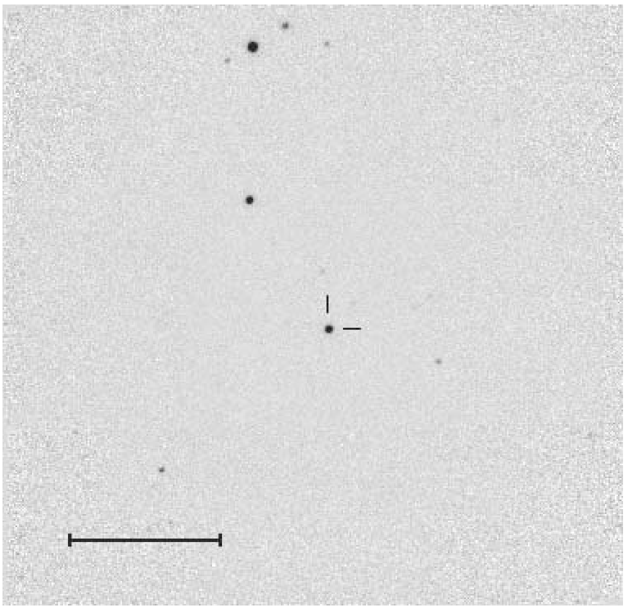
FS 04



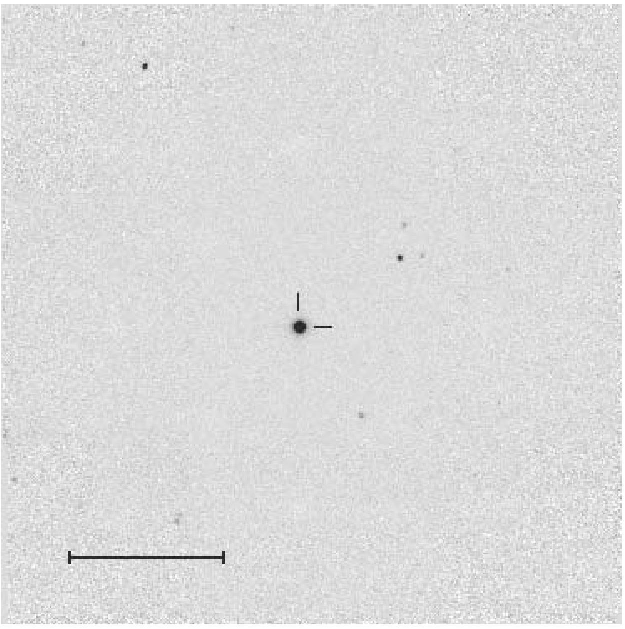
FS 05



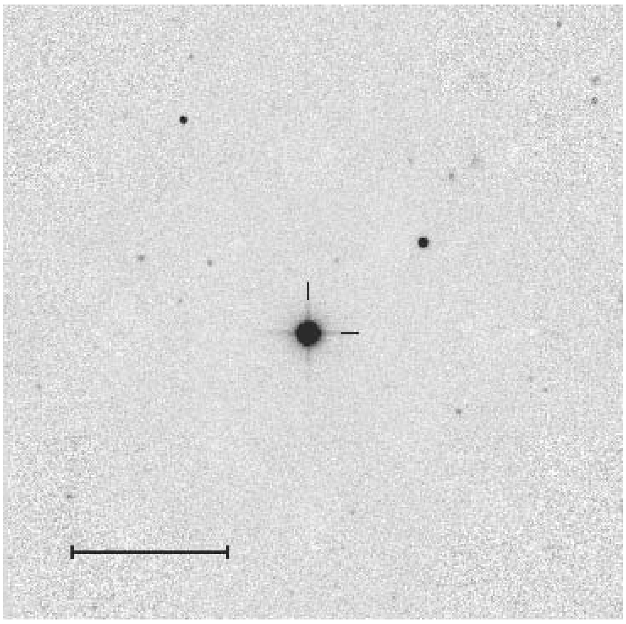
FS 06



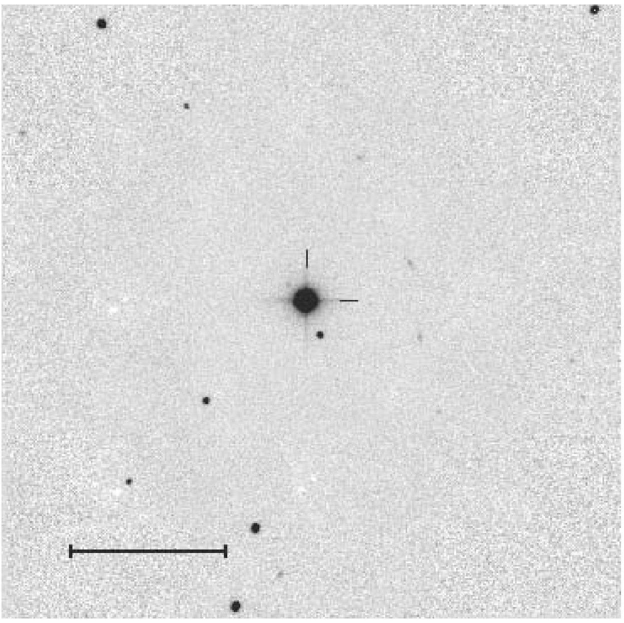
FS 07



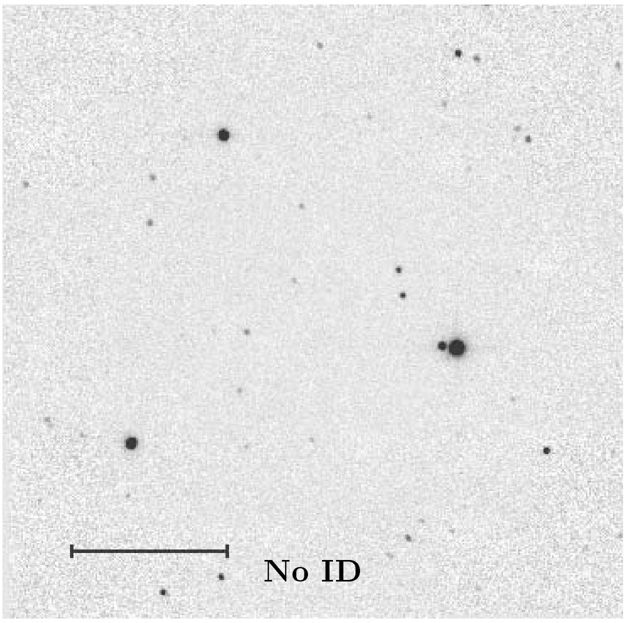
FS 08



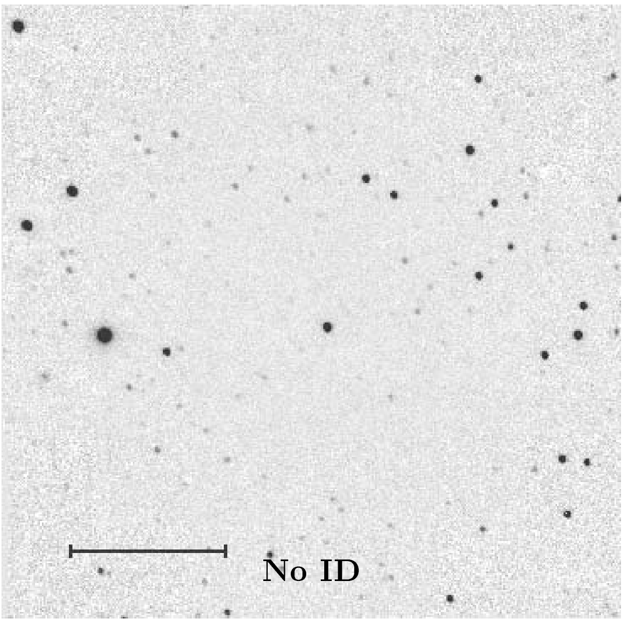
FS 09



FS 10



FS 11



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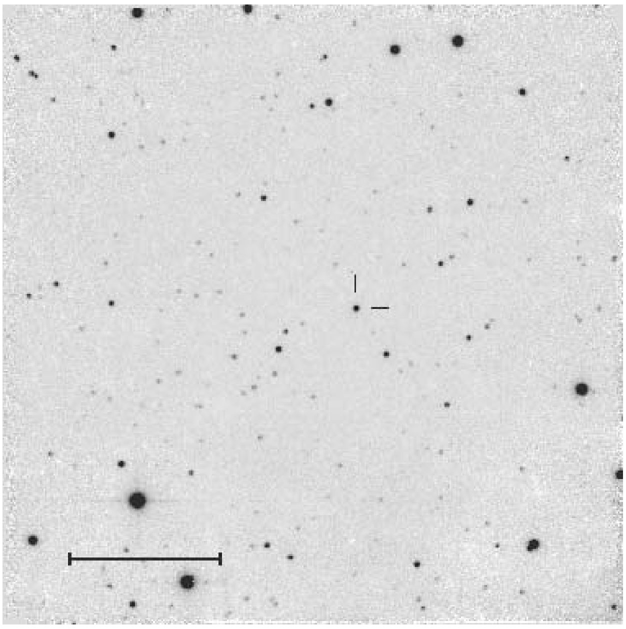

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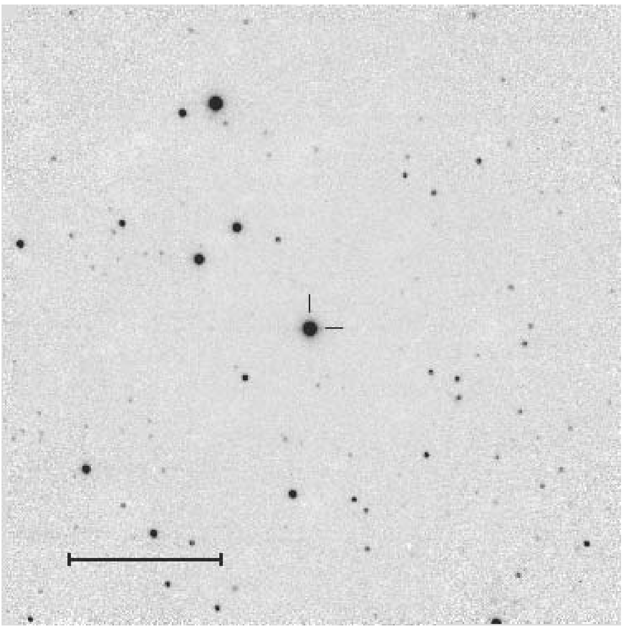
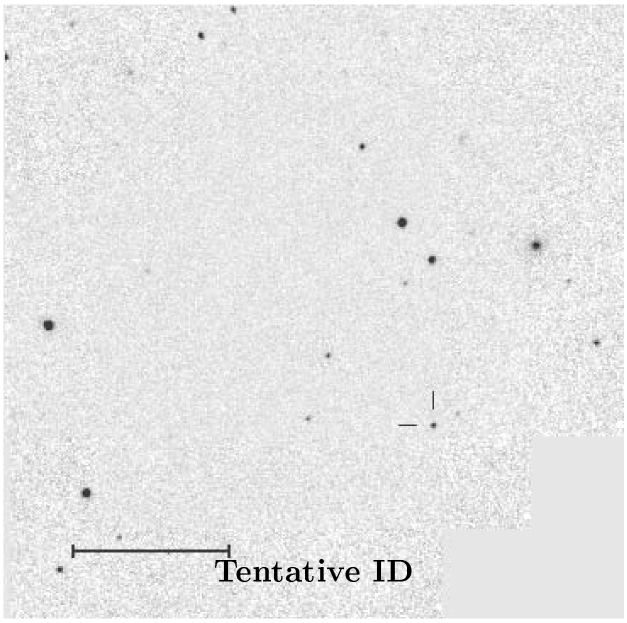
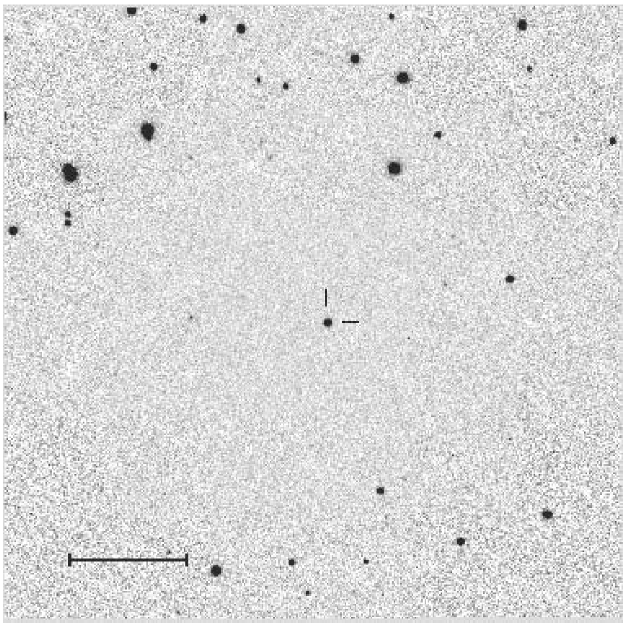


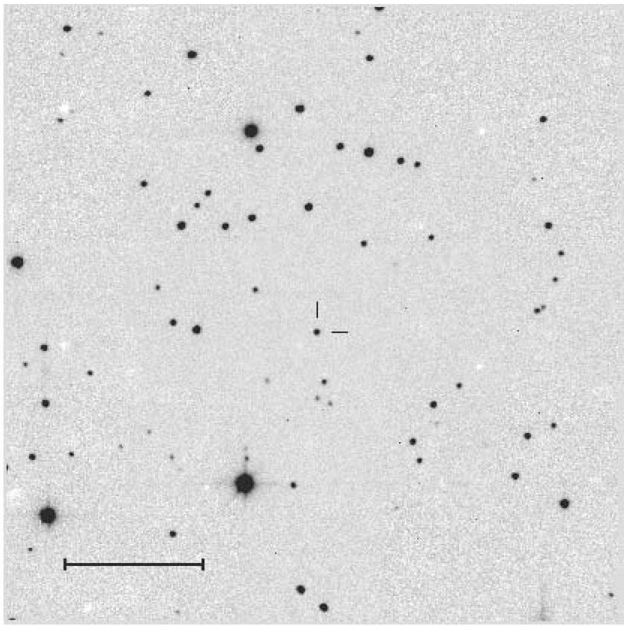
FS 14



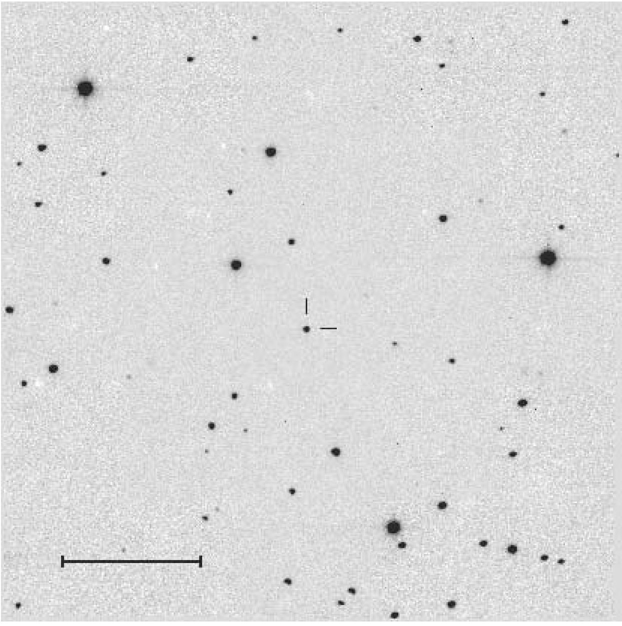
FS 15



FS 16

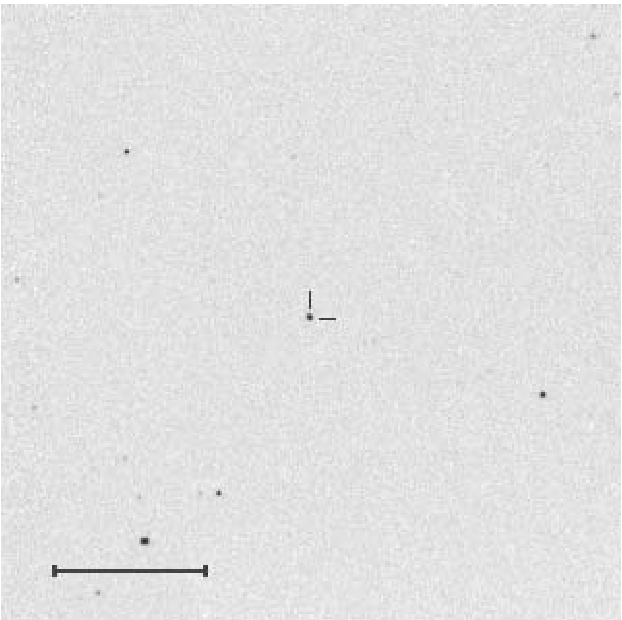


FS 17



FS 18

FS 19



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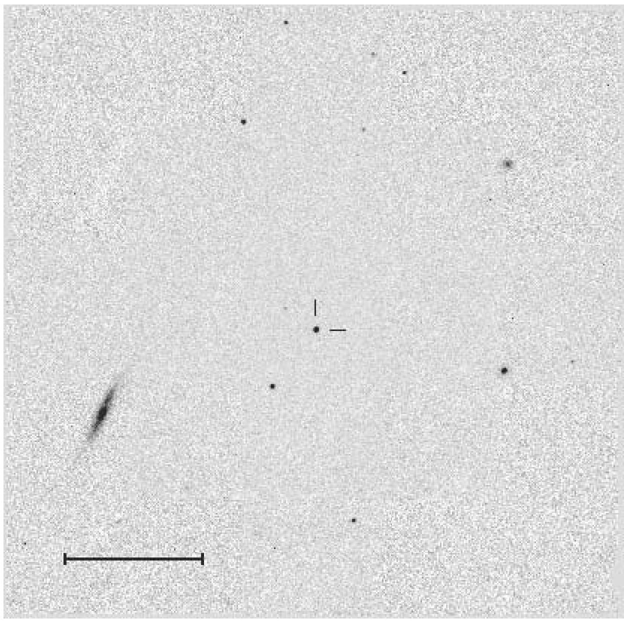

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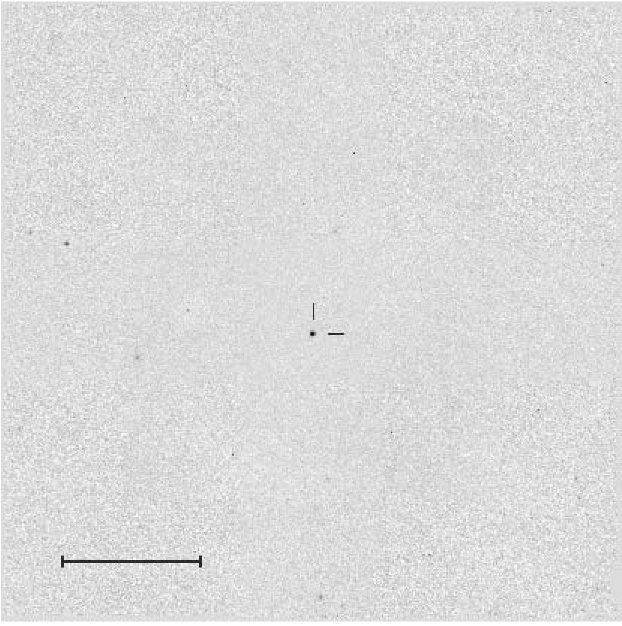

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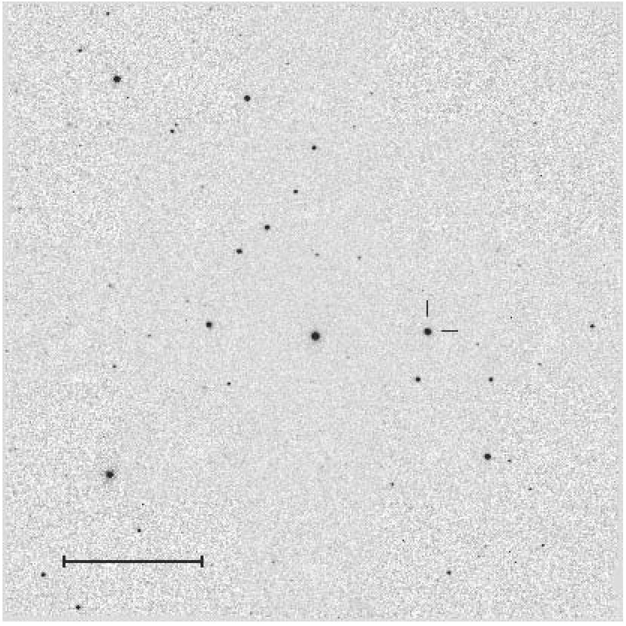

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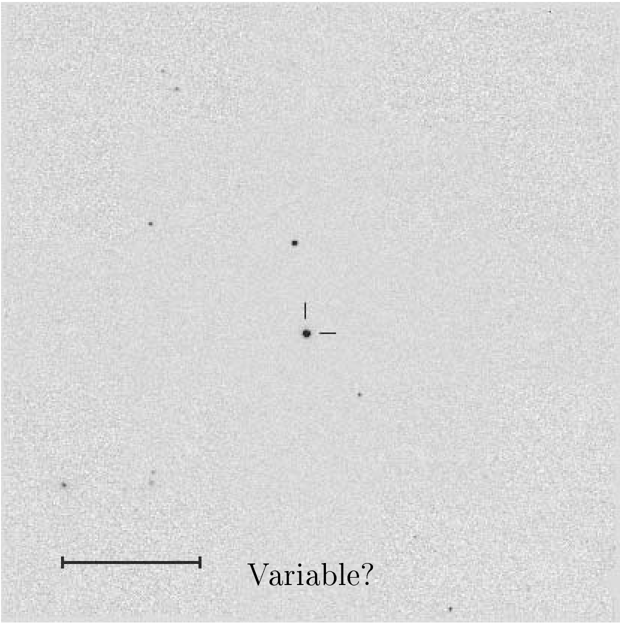

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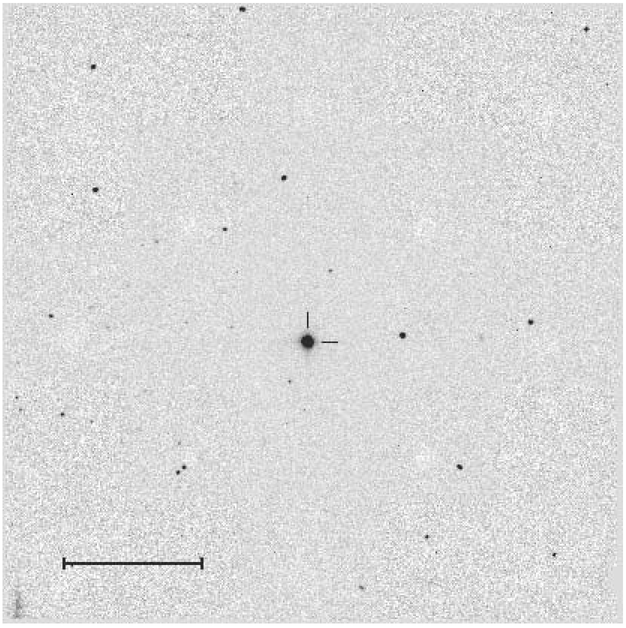
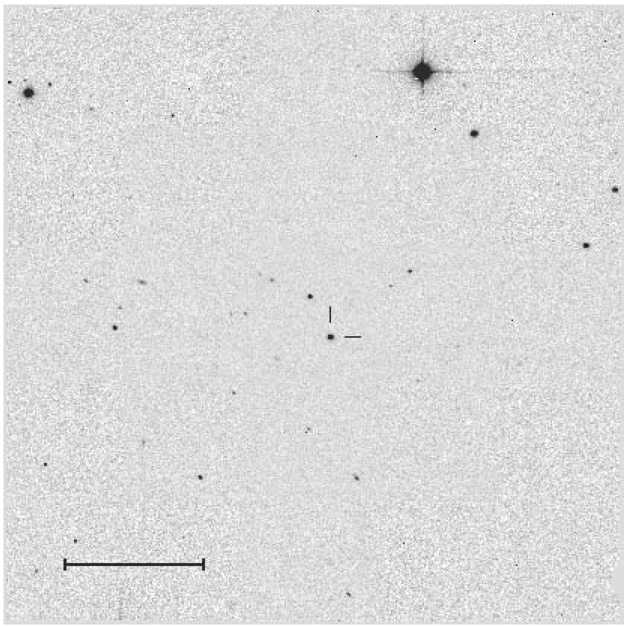


FS 26

FS 27



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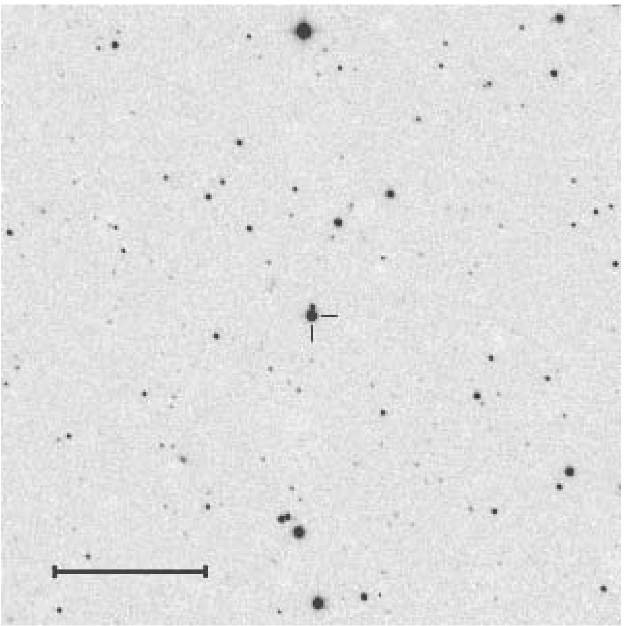

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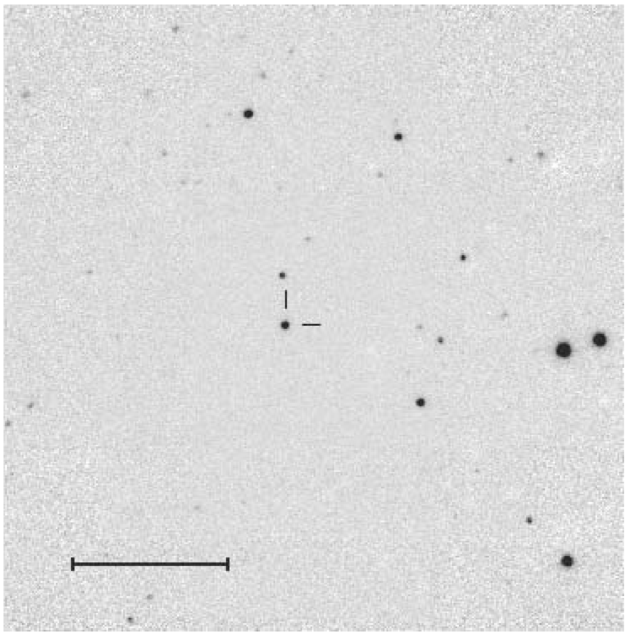

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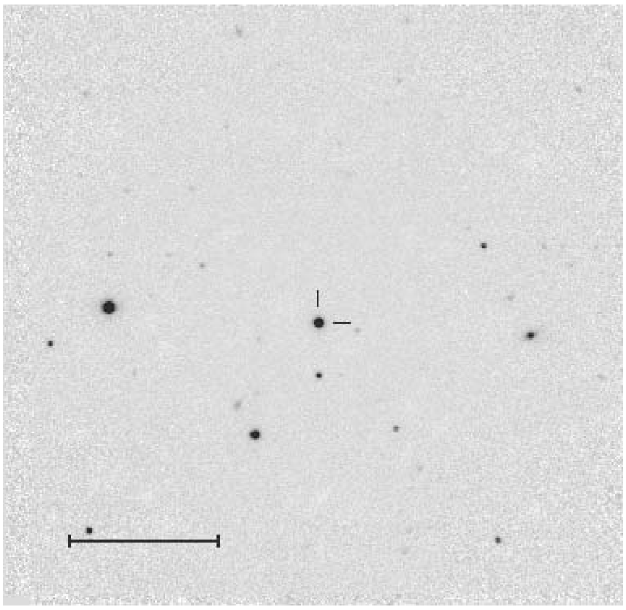

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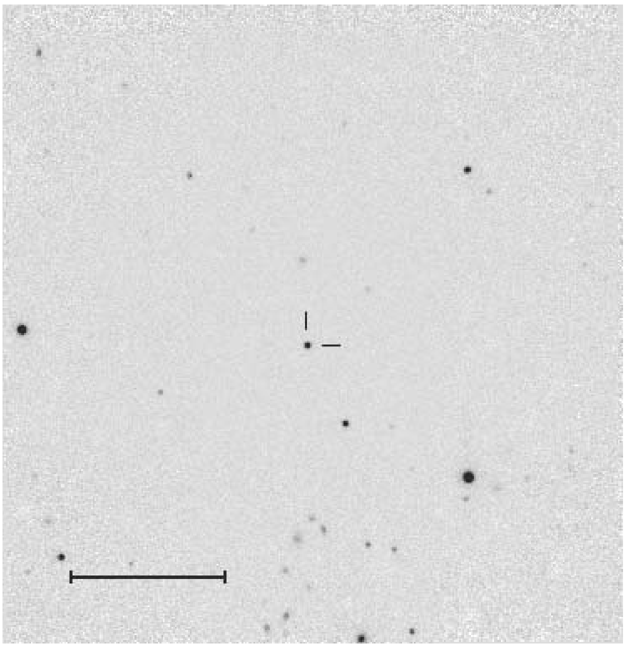

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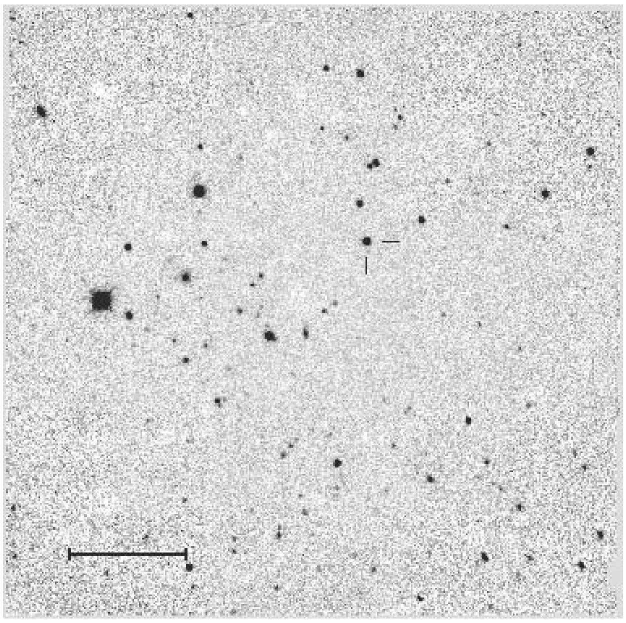

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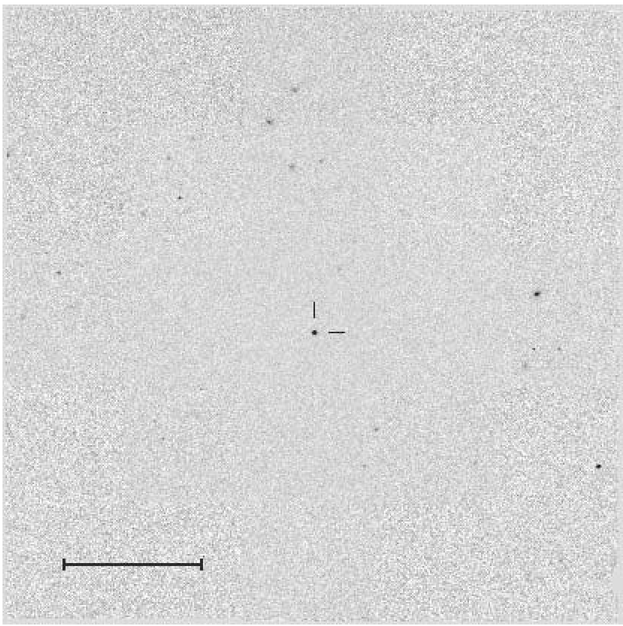

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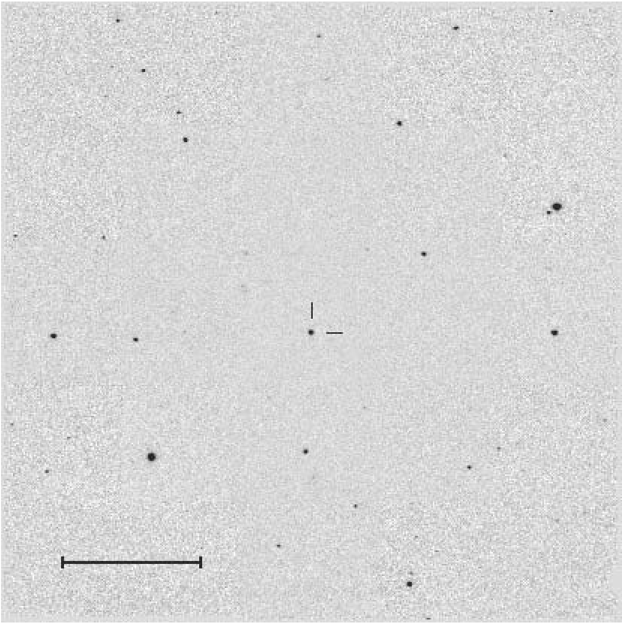

FS 35